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ORIGINAL PAPERS

THE DEFLOCCULATION OF CLAY SLIPS AND RELATED PROPERTIES[1]

BY E. W. SCRIPTURE, JR., AND EDWARD SCHRAMM

ABSTRACT

In an earlier paper[2] the authors have given the particle analysis and other tests of a number of English china clays, one English ball clay and several domestic kaolins. In this paper are presented the following additional data for the same clays: the carbon content as a measure of organic matter; the change in state of dispersion with pH for 20% slips as determined by settling tests; the change in viscosity with pH as determined with 40% slips; the alkali absorption for 20% and 40% slips. The more plastic clays are characterized by high organic content, high alkali absorption, and dispersion at low pH. Casting slips made up with the different china clays and two ball clays in varying proportions show that ball clay causes fluidity and that the plastic china clays produce more viscous slips than the less plastic.

I. Clays and Clay Slips

In an earlier paper[2] the authors have given the results of a particle size analysis of a number of clays and have shown a general relationship between particle size, state of dispersion, and physical properties. The most plastic clays were characterized by fineness of grain and partial dispersion when made up into 5% suspensions with water. Since this work was done we have encountered an English china clay (which we shall call No. 8) possessing an unusual combination of properties as follows:

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlanta, Ga., Feb., 1926. (White Wares Division). Recd. Dec. 28, 1925.

[2] *Jour. Amer. Ceram. Soc.*, **8**, 243–52 (1925).

Per cent of particles $< 1.7\mu = 43.8$
Suspension in water—flocculent
Modulus of rupture dry = 217 lbs. per sq. in.
Per cent drying shrinkage = 2.9
Per cent total shrinkage (cone 11 half over) = 8.8
Per cent absorption = 16.9
Per cent water of plasticity = 32.0

This clay was highly plastic as judged by feel, had a high dry strength and water of plasticity, and yet was of coarser grain than some of the tender clays (Nos. 1 and 2). It was noted that like most of the plastic china clays it possessed a yellow tone in the raw state although it fired very white. It appeared possible that some of the china clays might contain small quantities of organic colloids which would have an important influence on their properties. As a measure of the organic matter we determined the carbon content of the clays, reported in the earlier work, by ignition in a tube furnace and absorption in barium hydroxide. Blank runs were made treating the clays with acid to prove that the CO_2 did not arise from decomposition of carbonate. The results of these analyses follow:

CARBON CONTENT OF CLAYS

Clay No.	1	2	3	4	5	6	7	8	Eng. ball	Fla.	N. Car.
Per cent C	.024	.030	.034	.060	.035	.063	.049	.112	1.40	.135	.084

We note without exception low carbon content in the tender clays and increasing carbon as the clays increase in toughness and plasticity. It would appear that organic matter may play an important rôle in china clays as well as in ball clays although we have of course not shown directly any relation of cause and effect.

We frequently encounter references to the variability of china clays and an instructive experience along this line may be recorded here. With china clay No. 4 we obtained originally a dry strength of 180. On a later shipment we found 118. Redetermination of the particle size distribution and of the carbon content revealed no fundamental change. However, the new lot of clay gave a flocculated suspension with our water, whereas the old was partly dispersed and we were evidently simply on a different part of the curve of properties. To obtain a closer insight of the relationship between the various properties of clays, it was clearly essential to follow the change in properties of clay slips with alkali addition.

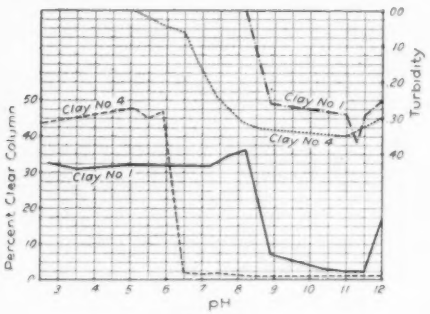

FIG. 1.

Hall[1] describes a method of following the changes of state of clay slips with *p*H of the medium and gives curves for a number of clays. We followed the principle of Hall's method, determining the dispersion by two methods: (1) the rate of settling expressed as percentage of clear column to total height (26 cm.) after 20 hours standing; (2) the turbidity expressed as the grams of solids in 10 cc. of slip taken from a point one inch below the top of the column after 20 hours standing, using NaOH and H_2SO_4 for controlling *p*H. (It will be obvious that the first method is best adapted to the flocculated zone (low *p*H) and gives most accurately the isoelectric point; while the second method is better in the deflocculated range and gives most accurately the point of maximum deflocculation.) The *p*H values were determined colorimetrically on the filtered slips. From the *p*H of slips made up with .02 *N*NaOH the absorption of alkali by the different clays was found. The results of this work are given below in tables and in the curves (Figs. 1 and 2).

TABLE I

SEDIMENTATION TESTS 20% SLIPS

China Clay No. 1												
*p*H	2.7	3.5	4.9	7.2	7.7	8.2	8.9	10.3	11.0	11.3	11.5	12.2
Per cent clear column	32.6	31.0	32.2	31.7	34.7	36.2	6.9	3.1	2.3	2.3	2.3	17.3
Turbidity							0.26	0.28	0.29	0.37	0.29	0.25
China Clay No. 2												
*p*H	0.6	1.5	1.7	5.0	7.3	7.5	8.7	11.0	11.3	11.9	12.2	12.3
Per cent clear column	39.3	40.0	40.8	38.8	41.5	44.3	1.5	1.3	1.5	1.5	1.5	9.6
Turbidity							0.07	0.14	0.12	0.07	0.06	0.05
China Clay No. 3.												
*p*H	2.2	2.7	5.0	5.6	6.25	6.35	6.5	7.1	7.5	8.1	8.4	9.5
Per cent clear column	42.0	41.6	35.1	36.1	36.0	38.2	40.5	37.6	39.8	38.6	7.7	2.3
Turbidity											0.01	0.16
China Clay No. 4.												
*p*H	2.5	4.1	5.1	5.5	5.9	6.5	6.9	7.4	8.1	8.6	11.0	12.1
Per cent clear column	43.7	46.2	47.8	45.0	46.8	1.9	1.5	1.9	1.2	0.8	1.0	1.0
Turbidity				0.02	0.04	0.06	0.15	0.24	0.31	0.33	0.35	0.30
China Clay No. 5												
*p*H	1.5	1.7	5.1	5.2	5.3	5.7	6.1	6.5	7.1	10.2	11.0	11.2
Per cent clear column	33.4	32.1	25.9	29.0	23.0	21.2	23.8	1.5	1.0	1.0	1.0	1.0
Turbidity								0.01	0.21	0.27	0.27	0.30

[1] *Jour. Amer. Ceram. Soc.*, **6**, 989 (1923).

China Clay No. 6

*p*H	1.8	2.2	4.5	5.2	5.6	6.0	6.3	6.8	10.0	11.3	12.2
Per cent clear column	23.0	31.5	37.0	33.0	16.2	15.4	5.4	1.5	0.8	0.8	0.4
Turbidity							0.10	0.32	0.30	0.28	0.29

China Clay No. 7

*p*H	1.7	2.0	7.1	7.2	7.3	7.4	8.7	10.0	10.7		
Per cent clear column	31.1	28.5	22.3	28.1	27.3	18.1	2.7	1.0	1.7		
Turbidity					0.07	0.41	0.52	0.58	0.47		

China Clay No. 8

*p*H	2.9	3.9	4.8	5.0	5.8	6.3	6.7	7.9	8.3	9.0	10.0	11.5
Per cent clear column	21.5	27.3	24.6	17.3	21.9	13.5	3.5	1.2	1.0	1.0	1.0	1.0
Turbidity					0.06	0.07	0.09	0.39	0.39	0.39	0.40	0.34

English Ball Clay

*p*H	3.1	3.7	4.3	4.9	5.0	5.1	6.1	6.3	7.8	8.4	8.9	9.5
Per cent clear column	23.2	24.7	31.8	34.1	36.0	36.0	2.3	0.8	0.8	0.8	0.8	0.8
Turbidity					0.01	0.01	0.02	0.43	0.43	0.50	0.56	0.51

Florida Kaolin

*p*H	3.5	4.1	4.9	5.0	5.2	5.3	5.4	5.6	5.9	6.2	7.2	8.0
Per cent clear column	41.6	42.3	40.2	41.4	39.6	40.6	40.3	39.8	38.9	40.8	2.2	1.5
Turbidity											0.04	0.32

Refined North Carolina Kaolin

*p*H	7.4	7.5	8.2	8.5	8.7	9.1	9.3	9.7	10.3	10.6	11.0	11.1
Per cent clear column	15.3	9.7	16.5	15.7	14.6	5.5	3.6	1.9	1.2	1.5	1.5	1.9
Turbidity								0.03	0.13	0.41	0.49	0.52

In the table below are given *p*H and *p*OH at the isoelectric points of the different clays, *i.e.*, the point preceding the sudden drop in height of clear column:

	*p*H and *p*OH at isoelectric point										
Clay No.	1	2	3	4	5	6	7	8	Eng. Ball	Fla.	N. Car.
*p*H	8.2	7.5	8.1	5.9	6.1	6.0	7.4	5.8	5.1	6.2	8.7
*p*OH	5.8	6.5	5.9	8.1	7.9	8.0	6.6	8.2	8.9	7.8	5.3

Twenty per cent suspensions were made of all the above clays using neutral water, *p*H = 7.0. The resulting values for *p*H were of similar magnitude to those reported by Hall and were as follows:

Clay No.	1	2	3	4	5	6	7	8	Eng. Ball	Fla. Kaolin	N. Car.
*p*H	5.1	5.5	5.5	4.8	5.1	4.6	5.1	4.6	5.1	4.3	5.0

To illustrate the differences between the various clays in absorbing capacity for alkali, we give below the percentage of the NaOH present absorbed by the clay in a 20% suspension in .02*N*. NaOH.

Clay No.	1	2	3	4	5	6	7	8	Eng. Ball	Fla. Kaolin	N. Car.
Per cent NaOH absorbed	48.8	46.7	40.3	91.1	50.2	74.9	47.2	85.9	96.4	88.9	76.5

In the curve (Fig. 2) we have plotted the following data for the different clays: *p*OH at isoelectric point; per cent carbon content; per cent NaOH absorbed; per cent fine particles ($<1.7\mu$); modulus of rupture dry. Other properties of these clays will be found in the earlier paper by the authors.[1] If we consider the curve and the data in the earlier paper there appears a rather striking relationship between the *p*OH at the isoelectric point, the carbon content of the clay, the absorbing power for NaOH, and the properties such as dry strength, shrinkage, and water of plasticity which are an index of plasticity. We are far from suggesting that all properties of clays can be expressed in terms of any one variable; but it does appear that the position of the isoelectric point which determines whether or not the clay is dispersed in a given sample of water and which in turn is related to the alkali absorption and the organic content of the clay, has an effect of prime importance on the physical properties of the clay, even in the plastic state.

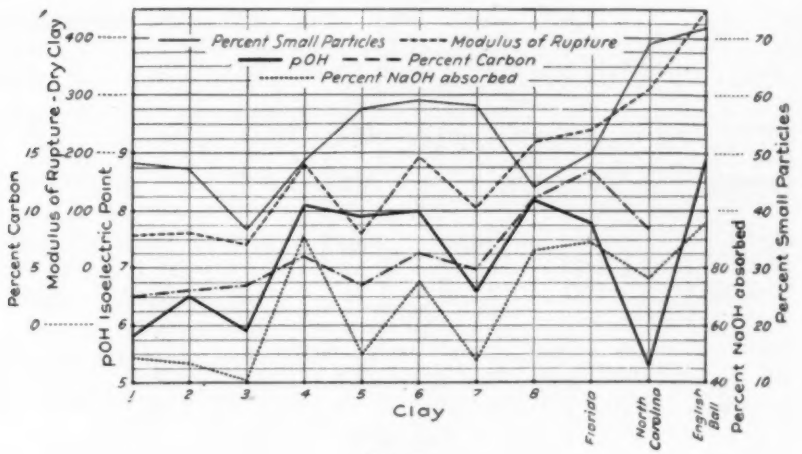

FIG. 2.

To observe the change in state of the clay slips by a physical method which would cover the whole range, it was decided to determine the viscosity-*p*H curves. Viscosities were measured by means of the simple flow type of viscosimeter described by Bleininger.[2] To get a

[1] *Loc. cit.* p. 51.
[2] Bur. Stand., *Tech. Paper*, **51**.

sufficient range of measurements it was necessary to work with slips containing 40% clay. The filtration of these slips in the deflocculated state proved a difficult task. Such slips will filter clear only after a bed of clay has been built up on the filter, but at this point filtration by ordinary means becomes impossible. To overcome the difficulty we constructed a small filter press of brass pipe and flanges, employing a filter of regular press cloth. After the slip was introduced, air pressure was applied and after a short time a clear liquid was obtained. All the slips were made up in a similar manner, allowing the clay to soak over night in distilled water, then blunging with successive small additions of 10 *N* NaOH. After 20-minute blunging the viscosity was determined and the slip filter pressed for the *p*H determination. In each case the specific gravity of the slip was 1.32 ± 0.015. We give below the results for the different clays in terms of relative viscosities, OH′ added in mols. per l. of water present, and *p*H of filtrate. Relative viscosity $= 1.32 \times \frac{\text{time of flow for slip}}{\text{time of flow for water}}$.

TABLE II

Clay No. 1

[OH′]	.0	.0019	.0038	.0063	.0091	.0124	.0166	.0220	.0303
*p*H	5.2	6.3	6.7	7.3	9.1	10.0	11.1	11.4	12.1
Viscosity	2.82	2.26	2.26	2.20	2.08	1.93	1.83	1.78	1.81

Clay No. 2

[OH′]	.0	.0019	.0038	.0063	.0091	.0124	.0166	.0220
*p*H	7.5	7.8	7.1	8.5	10.5	11.1	11.7	
Viscosity	2.23	2.11	1.97	1.72	1.61	1.57	1.54	1.51

Clay No. 3

[OH′]	.0	.0038	.0105	.0161	.0226	.0310
*p*H	5.8	6.9	10.1	11.0	11.2	11.7
Viscosity	1.87	1.83	1.76	1.65	1.62	1.60

Clay No. 4

[OH′]	.0	.0019	.0038	.0063	.0091	.0124	.0166	.0220	.0303
*p*H	4.9	5.2	5.5	5.7	5.9	6.1	6.4	7.0	7.7
Viscosity	2.20	2.02	1.87	1.78	1.72	1.65	1.60	1.54	1.65

Clay No. 5

[OH′]	.0	.0019	.0038	.0063	.0091	.0158
*p*H	5.1	5.4	6.0	6.9	7.4	9.1
Viscosity	2.34	2.06	1.75	1.62	1.57	1.62

Clay No. 6

[OH′]	.0	.0019	.0038	.0063	.0091	.0124	.0166	.0220	.0303
*p*H	5.1	5.5	5.7	6.0	6.3	6.7	6.9	7.5	9.1
Viscosity	3.96	3.09	2.52	2.23	2.04	1.69	1.65	1.62	1.62

Clay No. 8

[OH′]	.0	.0019	.0038	.0063	.0091	.0124	.0166
*p*H	6.3	6.5	6.9	7.1	7.4	7.9	
Viscosity	2.06	2.02	1.78	1.76	1.66	1.69	1.74

	English Ball Clay						
[OH']	.0	.0019	.0038	.0063	.0091	.0124	.0166
*p*H		6.1	6.3	6.9	7.0		
Viscosity	2.70	2.78	2.24	1.78	1.57	1.50	1.47

	Florida Kaolin							
[OH']	.0	.0038	.0079	.0126	.0154	.0188	.0228	.0285
*p*H	6.9	6.9	7.3	7.5	7.9	8.0	8.3	9.1
Viscosity	No flow	No flow	No flow	4.16	2.38	2.02	1.81	1.74

The relative viscosities are plotted against *p*H in the curve, Fig. 3. These curves are of the same general shape and location as the turbidity and settling curves plotted from the data previously given. Marked differences are observed in the viscosities of the different English china clays without addition of alkali, but at minimum viscosity the differences are slight. The drop in the viscosity curve occurs at a lower *p*H for the more plastic clays but not necessarily at a lower alkali addition because of the higher absorption of these clays. The English ball clay slip reaches a lower minimum viscosity than any of the china clays. Florida kaolin slips are characterized by high viscosity.

In Fig. 4 we have plotted the *p*H against the mols. per liter of OH' added to the liquid. The broken line is the theoretical curve for the case of no absorption. The departure of the actual curves from this represents the relative absorption of OH' by the different clays. The results are in agreement with the data previously given for 20% slips and show a greater absorption by the more plastic clays.

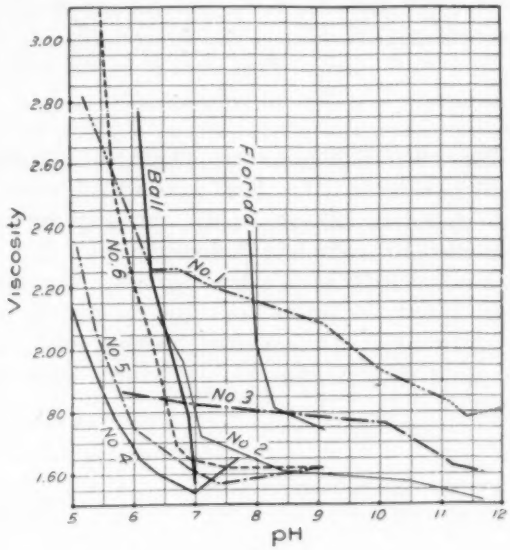

FIG. 3.

II. Body Casting Slips

We next turned our attention to the properties of clays affecting their behavior in casting slips. In the symposium on casting[1] there is a discussion of the question, "What measures should be taken for correcting a slip that requires excessive electrolyte?" Sharply divergent views

[1] *Jour. Amer. Ceram. Soc.*, **8**, 567–70 (1925).

were expressed as to the behavior of ball clays in casting slips, whether a high content of such clays aided or impeded the production of a low viscosity slip. It could only be supposed that different ball clays might behave in an opposite sense, or perhaps that the same ball clay might exhibit differing behavior under different conditions. Information on this point may be found in the papers by Gerber and by Foltz.[1] To throw further light on the question of the action of different kinds of clay in casting slip we decided to study the behavior of the several clays when used under approximately working conditions. For this purpose mixes were made up containing 50% clay, 30% flint, 20% feldspar. To these were added water to produce a slip containing 67% solids (sp. gr. 1.72), and sodium carbonate below the amount needed for complete deflocculation. The mixtures were run overnight in a ball mill with a few pebbles. The slips so prepared were allowed to stand 24 hours and the viscosities determined after successive additions of concentrated Na_2CO_3 solution. Besides running the individual slips in this way, mixtures were made of china clay and ball

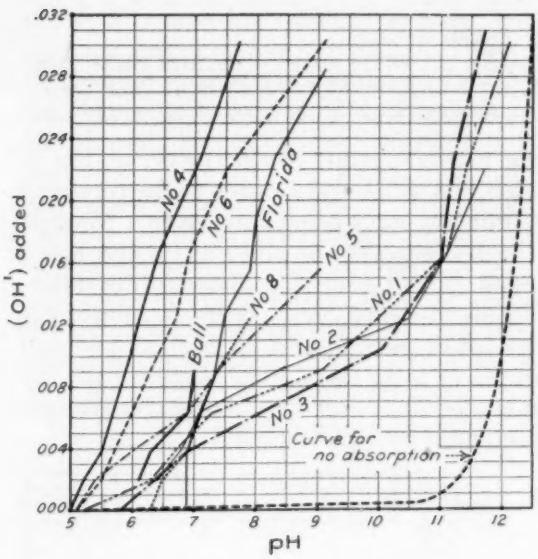

FIG. 4.

TABLE III

	Minimum Viscosity					
Per cent dark ball clay	0	5	12.5	25	37.5	50
Per cent china clay	50	45	37.5	25	12.5	0
China Clay						
No. 1	12.75	4.71	3.32	——	——	——
No. 2	10.10	5.34	3.80	3.41	2.86	3.20
No. 3	8.72	4.41	3.44	——	——	——
No. 4	No flow	No flow	17.8	8.50	——	——
No. 5	14.1	7.75	4.71	4.32	——	——
No. 6	No flow	19.7	6.36	4.56	3.05	3.29
No. 8	No flow	No flow	No flow	7.9	——	——

[1] *Jour. Amer. Ceram. Soc.*, **8**, 18 and 383 (1925).

Per cent Na_2CO_3 for Minimum Viscosity						
Per cent dark ball clay	0	5	12.5	25	37.5	50
Per cent china clay	50	45	37.5	25	12.5	0
China Clay						
No. 1	0.27	0.23	0.27	——	——	——
No. 2	0.29	0.33	0.29	0.29	0.26	0.33
No. 3	0.25	0.25	0.23	——	——	——
No. 4	——	——	——	0.17	——	——
No. 5	——	——	0.15	0.17	——	——
No. 6	——	0.15	0.19	0.27	0.33	——
No. 8	——	——	——	0.33	——	——
Mixtures of Blue Ball Clay and China Clay No. 2						
Per cent blue ball	0	5	12.5	25	37.5	50
Per cent china clay No.2	50	45	37.5	25	12.5	0
Minimum Viscosity	10.1	6.64	5.49	4.23	3.83	3.80
Per cent Na_2CO_3	0.29	0.33	0.25	0.29	0.33	0.37

clay slips in varying proportions. A number of different china clays were run with a dark English ball clay and one china clay with a blue ball clay to afford a comparison of these two types of ball clay. The results are given in the preceding tables, the numbers representing relative viscosity and Na_2CO_3 added in per cent of solids present.

Blue ball clay was also tried in combination with No. 4 china clay (25% of each) but it was not possible to produce a slip which would flow. A mixture containing 25% dark ball clay and 25% Florida kaolin also failed to flow.

The data for china clay No. 2 in combination with ball clay are plotted in Fig. 5. We are now in a position to return to the original question as to the effect of increasing or decreasing the ball clay content of a casting slip. From an examination of the curves and tables it is apparent that the important question is not how much alkali need be added to produce minimum viscosity, but how low a minimum can be reached with the different combinations. With all china clay, no low viscosity slip can be prepared. The introduction of a small amount of ball clay results in a sharp lowering of minimum viscosity which continues to fall more gradually with further increase in ball clay content. With dark ball clay the lowest viscosity is reached

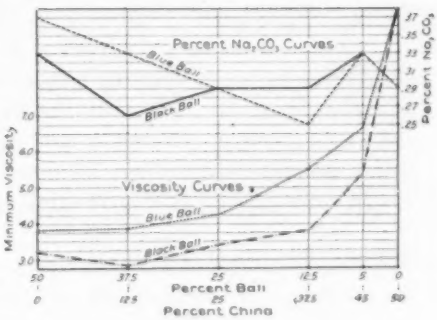

FIG. 5.

in the slip containing 37.5% ball to 12.5% china clay, although the slip with all ball clay gives a figure only slightly above this low value. In the case of the blue ball the minimum is reached with the all ball clay slip.

It is therefore apparent that within the range of practical working compositions an increase in ball clay will give increased fluidity to casting slips. How much ball clay need be used for this purpose depends on the nature of the china clays. The more tender or non-plastic the china clay, the smaller the proportion of ball clay needed to produce a fluid slip. Thus, with china clays 1 to 3 we obtain low viscosity with only 5% of ball clay, with No. 5 we reach a similar condition with 12.5% ball clay, with clay No. 6 we must go to 25% ball clay, while with Nos. 4 and 8 no fluid slips were obtained even with equal quantities of ball and china clays. We thus have the apparent paradox that while the highly plastic ball clays confer fluidity on a casting slip, the more plastic of the china clays have the directly opposite effect.

Considering the behavior of the dark and blue ball clays, it appears that the former gives more fluid slips under like conditions, although the differences are not so pronounced as between different china clays.

As previously remarked, the differences in amount of alkali required do not appear significant and do not follow any simple law. We know from the work done on the simple clay slips that the ball clay is deflocculated at a low *p*H (on the acid side of the neutral point) but has a high absorption factor while the china clays deflocculate at higher *p*H (on the alkaline side) but have lower absorption factors. We are therefore dealing in both cases with opposing effects and the amount of alkali required for the dispersion of mixtures is the resultant of a complex series of properties.

LABORATORY OF ONONDAGA POTTERY CO.
SYRACUSE, N. Y.

THE USE OF OVERGLAZES FOR POLYCHROME TERRA COTTA[1]

By A. Lee Bennett

ABSTRACT

The flexibility and economy of single-fire overglazes as compared with other polychrome methods are emphasized. Insoluble materials are preferable. A base white overglaze formula and its preparation and application are given. These single-fire overglazes have been used commercially with excellent results.

Introduction

At present a gradual increase in the use of color in architecture is taking place. With it has been a very considerable increase in the number of terra cotta jobs which are strictly polychrome treatments. Frequently, for a considerable tonnage, three, four, or even more colors are used on each piece of terra cotta. If the colors are obtained entirely by the application of glazes by spraying, work of this character may be quite expensive to manufacture both from the standpoint of time and labor expended.

Polychrome Methods Previously Used

Painting of Colored Glazes

Some savings may at times be effected by painting the glazes on to some of the polychromed areas. However, in the writer's opinion, the painting of glazes cannot be considered as satisfactory as spraying them on to the terra cotta. In the first place the average spray or glaze man in a terra cotta plant cannot be depended upon to do a first-class job of painting. Neither is any other properly trained help usually available. Also, if the glazes are painted on the ware, it is frequently difficult to prevent certain very apparent defects due to their being applied too heavy or too light, such as dryness, pinholing or crawling.

These variations in glaze thickness will also tend to cause variations in color which may be undesirable. In addition, the process of painting glaze is frequently quite laborious and may also not present any considerable saving of time as compared with masking of various areas and spraying the glazes. This is especially true if the colored areas are of any considerable size.

Soluble Salts

Another possibility for polychroming terra cotta is the production of some of the desired colors either by spraying or painting solutions of soluble metallic salts on the body glaze of the terra cotta.

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[1] Presented at meeting of Pacific-Northwest Section, American Ceramic Society, Seattle, Washington, January 30, 1926. Received January 9, 1926.

Usually with this method of polychroming, the glaze which produces the principal color of the job is applied over the entire surface of the ware and allowed to dry. Then certain soluble salt solutions of definite concentrations are painted or sprayed on to the desired colored areas. Frequently, of course, when the soluble stains are applied by spraying, portions of the piece must be covered so as to prevent any of the solution from falling outside of the areas which are to be colored. Necessarily, any covering of the ware involves considerable time and labor. Also, in spite of such covering, the solution may run under it and stain the adjoining areas. If the solutions are painted on there will sometimes be a tendency toward considerable variations in color, although this may not be a very serious defect. However, we have found in actual practice that our greatest difficulty with soluble salt solutions was the fact that they frequently loosened the glaze coat on which they were applied so that when dry, the glaze would crack and at times fall off the piece, or else, it frequently crawled during the firing of the ware. At present, except for the polychroming of very small areas, we do not attempt to use soluble salt solutions.

The Use of Overglazes for Polychrome

Description and Properties

One other possible method is the use of overglazes to produce various color effects in a single firing of the terra cotta.[1] This process certainly presents excellent possibilities. An overglaze is substantially a mixture of ceramic chemicals preferably insoluble in the liquid used to render them fluid and containing little or no colloidal "clayey" material, which may be applied over the usual glaze when dry and which will develop a glaze texture and consistency upon firing. That is, it consists largely or entirely of non-plastics which will fuse and vitrify on the surface of the glaze itself. Certain of the ingredients may, of course, be chemicals which are ordinarily plastic but which have been rendered non-plastic by calcination. Naturally, such a material or mixture of materials will under ordinary conditions dry very rapidly since it may require but little water, or possibly some other satisfactory liquid, to render it properly fluid and also because of the fact that it does not tend to retain its water or other liquid content as it would if it contained colloidal materials. When dry an overglaze is powdery and does not cohere and knit together like an ordinary terra cotta glaze, for instance, since no colloidal or "setting" action takes place as it drys. Of course, no gum tragacanth, gum arabic or their equivalent is used in the overglazes.

[1] Hewitt Wilson, "Overglaze Colors at Cones 6–7," *Trans. Amer. Ceram. Soc.*, **19**, 653 (1917).

These, then, are several of the most important properties of true overglazes. As you can see, a true overglaze is a very workable medium for the application of colors. It can be sprayed in an even coating on the surfaces of the ware which are to be polychromed or we have found that frequently it may be painted on with considerable success. Once applied it adheres sufficiently to the terra cotta glaze beneath it so that it will never fall off, nor be at all easily blown off, when dry. It can, of course, be brushed off, this being one of the most important of its properties. Wherever any overglaze is in contact with areas of the ware which are not to be colored by it, it can be so completely removed by brushing with a rather stiff bristled camel's hair or similar brush that the surfaces of the body glaze will come through the kilns clean and "on color." Also since the overglaze does not tend to knit tightly to the dry surface of the terra cotta glaze, this brushing can be done fairly easily and rapidly if only a fair degree of care is exercised.

Colors Developed At the present time we have developed at cone 6 numerous overglaze colors running from white through strong creams to yellows, various shades of brown, blues, greens, blacks, etc., with possibilities, of course, for the development of other colors and the usual limitless combinations of the present palette to give composite shades.

Difficulties One difficulty encountered in the development and use of overglazes is their tendency toward translucency. Also, the fact that their "color reactions" may be influenced by the character of the glaze upon which they are superimposed. Recent tests tend to demonstrate that increasing the concentration of the tin oxide used as an opacifier will eliminate much of the variation in color which may be due to either of these causes.

Another overglaze problem is the fact that some overglazes apparently cannot be resprayed and refired to identically their original color. This seems to be true mainly of those containing fairly large amounts of cobalt oxide or stains containing cobalt.

Suggested Formula We suggest a base white overglaze having the following molecular formula:

$$\left.\begin{matrix} 0.621\ ZnO \\ 0.379\ CaO \end{matrix}\right\} 0.453\ Al_2O_3 \left\{\begin{matrix} 1.324\ SiO_2 \\ 0.126\ SnO_2 \end{matrix}\right.$$

$$1.000$$

Various shades of different colors may be obtained by blending the proper stains or coloring oxides with the above overglaze. It is made up entirely from either calcined or non-plastic materials.

Preparation Practically all overglazes are weighed up with about 80% water to the weight of dry overglaze. They are then ground in small pebble mills for three hours. The stains or other coloring ingredients are usually ground separately with the proportions of water and grinding time the same. Then the base overglaze and ground color are screened through at least 100-mesh and blended in the liquid state, in the proper proportions.

Application The mixed overglaze is sprayed on the terra cotta using a very fine spray gun. Our gun is of a suction type and we vary the air pressure between 7 and 10 pounds per square inch depending on the type of overglaze and how it atomizes.

Two even coats are usually applied. A "coat" is applied by spraying over the surface of the piece twice, the second application being at right angles to the first. The overglaze when properly applied is dry and "fuzzy" in appearance and does not cause the dry glaze underneath to blister because of becoming too wet.

Wherever necessary, we cover such adjoining areas of a piece as are not to be colored by the overglaze. The actual covering need not be exact, as the overglaze is easily removed wherever it is in contact with areas other than its own. The method which we have usually employed for the masking of portions of a piece of terra cotta is to cover them with plastic clay (regular terra cotta body) with newspaper separating it from the surface of the piece.

Where only an ornament is to be colored and not the flat backgrounds, pieces of thin sheet iron are cut to the size approximately of the background areas. After spraying, we have found the sheet iron templet to be quickly and easily lifted off with a magnet.

Commercial Use In the actual production of all our recent polychrome jobs, overglazes have been made use of quite extensively.

The jobs have all had from 300 to 500 square feet of strictly polychrome terra cotta, with from two to as many as seven or more colors in addition to the body color of the job on each piece. Most of the colors were produced by overglazes.

Conclusion

I can state definitely that thus far we have found the overglaze method of polychrome both interesting and practical. We certainly hope to satisfactorily develop it further.

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DE-AIRING AS CORRECTIVE IN DRYING[1]

By Fred Brand

ABSTRACT

The physics of mechanical removal of water from clay involves character of pores, adsorption capillarity and it also involves air filled cavities. Theory of clay particle system when plastic is set forth and argument is made for the effect of air on water removal and on drying shrinkage.

Introduction

Seeking for the cause of the phenomenal improvement in drying qualities found in de-aired clays has led to the conclusion that none of the usual theories adequately covered this important phase of ceramic manufacture. We shall not review the various methods used to improve the drying quality of clays but we shall consider some of the theories concerning the fundamental causes for differences in drying behaviors. These theories assume that the drying quality resides within the clay itself which assumption is held not to be altogether according to the facts.

Statement of Current Theory

Perhaps the best general statement of the more current theories is as follows:[2]

In making up dry clay with water to form a plastic mass which may be shaped and molded, the resulting volume is somewhat greater than the sums of clay and water. In this condition the clay particles, both plastic and granular, are surrounded on all sides by a film of water, while small pools or drops fill the cavities and pores between the grains. A tortuous system of capillaries is thus established which are wider in some places and narrower in others. When placed in an atmosphere saturated with moisture, equilibrium conditions are reached when no flow of water whatever takes place in these minute channels. As soon as the humidity is lowered, however, evaporation begins to take place at the surface, and every particle of water thus removed must be replaced through the capillary channels from the interior. The rapidity of this movement depends upon the structure of the clay—*i.e.* whether the capillaries are fine and intricate[2] or coarse and short—and upon the temperature and humidity of the outside air. Open structure, high temperature, and low humidity result in maximum capillary flow and vice versa. Since the spongelike colloidal matter with its immense surface and fine pores offers the greatest resistance to the passage of water, it is obvious that in highly plastic clays the movement of the water through the capillaries must be very slow, it having been estimated that the resistance to this flow is inversely proportional to the fourth power of the diameter of the channels. The capillary flow continues to grow weaker until the films become very thin and finally break altogether. The water remaining within the colloidal interstices and within the pores in isolated films is expelled with increasing difficulty, and, owing to its low vapor pressure, requires a high temperature for its complete expulsion. Clays are subject to two kinds of difficulties which are opposite in character. They may give trouble, due either to an excess of plastic material or to a deficiency of it; in the first case the system of capillaries is so extremely fine that the flow of water through it is very slow and becomes the more restricted as shrinkage progresses. Owing to the fact that such clays show a very large contraction in volume,

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (Heavy Clay Products Division). Received Dec. 26, 1925.

[2] A. V. Bleininger, Bur. Stand., Tech. Paper, **1**, No. 1.

the capillary channels become smaller and smaller on drying, thus causing the difficulty of expelling the water to increase. The result is inevitably that the rate of surface evaporation is greater than the flow of water toward the surface, a condition which gives rise to strains and more or less marked ruptures.

In the second case the amount of clay bonding matter is so low that the body does not possess the tensile strength needed to withstand the strain caused by the closing up of the particles near the evaporating surface. The result of this is that the clay gives way and cracks.

In order to overcome these two classes of difficulties some remedial measures are available. These are, for the excessively plastic clays, dilution by means of non-plastic materials like sand or ground, calcined clay (grog), or drying the ware under carefully regulated conditions with special reference to the maintenance of high humidity in the drying until the clay has become uniformly heated throughout, or by using the preliminary heating treatment which is the subject of this work.

In regard to weak clays, lacking in plastic matter, the method for overcoming the difficulty consists in developing the available plasticity to its maximum by means of storing in the wet condition, by grinding and thorough pugging, by the use of slightly acid tempering water (in some cases), and finally by the incorporation of a more plastic material, which offers the most positive solution of the case.

The addition of granular, non-plastic material to an excessively plastic clay is made for the purpose of improving the working quality by reducing its "stickiness," decreasing the drying shrinkage, and with it, the tendency to warp and crack in drying, and of lowering the kiln losses due to strains caused in drying.

If in the case of a difficultly drying, exceedingly plastic clay it is decided to add sand for the purpose of making it easier to dry, this addition should be carried beyond the point of maximum density, so that a larger pore space, and hence an increased evaporation and outlet area, is produced.

The fact that clays generally more or less improve by the treatment indicated makes it appear that the underlying causes of the difficulties and the manner of improvement are as stated by Mr. Bleininger. His explanations, however, do not cover the situation in its entirety. In the case of the feebly plastic clay, why should there be a marked closing up of the surface particles in a clay low in plastic material? Why would not the addition of plastic material also increase this tendency along with the stresses?

Effect of Non-Plastics on Rate of Water Removal

While it is true that in treating a plastic clay with granular material the best results are obtained when the additions are "carried beyond the point of maximum density," yet improvement begins to manifest itself, especially if the clay be worked in the auger machine, long before this point is reached, and throughout the series of additions the plastic material continues to be the fine-pored system through which water must find its way to the surface. Even when the proportion of coarse non-plastic is so large that the fine-pored material is no longer sufficient to fill the voids, giving a so-called "open-pored" mass, there is no freer

movement of water to the surface. In fact Bleininger[1] on page 36 says in part as follows:

> In every case it was found that the rate of drying of the preheated clays was identical with that of the normal materials, though, of course, the amount of water required to develop plasticity differed in the preheated materials from the normal amount. In Fig. 7, the curves of clay No. 1 are presented which are typical for all of the materials tested and show clearly that preheating does not influence the rapidity of drying.

Yet in the one we would assume that the capillaries were "coarse and short" and in the other, "fine and intricate" where "the movement of the water through the capillaries must be very slow."

Again, the shrinkage and loss of water curves obtained by Lines[2] show no lag in the rate of drying until two hours after shrinkage had ceased, though of necessity the channels became constantly narrower as drying progressed. Thus if the resistance to the capillary flow is inversely proportional to the fourth power of their diameters, it follows that water diffusion through a clay mass is not due to capillarity in the same sense as water rising in a tube. While loss of weight cannot be proportional to actual replacement to the surface, yet we could reasonably expect a constantly increasing lag as the surface of the water receded from the surface of the mass, if surface replacement was by capillarity.

Drying Time Dependent on Shrinkage

While it is no more difficult to remove water from a sticky plastic clay than from a leaner one, the fact remains that considerably more time is required to safely remove the water from the more plastic clays. Bleininger, to arrive at the approximate time requirements under commercial conditions, multiplies the shrinkage by the time required to remove the shrinkage water under laboratory conditions. Thus in a clay having a shrinkage of 4% and dried in four hours, the answer was 16 hours under commercial conditions, while in a clay shrinking 8.5% in the drying and requiring 8.9 hours the answer was 75.55 hours under commercial conditions.

The Physics of Water Additions

Since the rate of water loss in these two clays is practically the same, why is not the commercial time requirement proportional to the amount of work done?

Regardless of type, clays are made up of varying percentages of various mineral particles, and aggregates of varying degrees of porosity

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[1] *Loc. cit.*

[2] E. F. Lines "Notes on the Drying of a Clay," *Trans. Amer. Ceram. Soc.*, **10**, 146 (1908).

ranging from coarse to submicroscopic. Let us assume that water is added a portion at a time in quantities just sufficient to meet each individual requirement of the mass.

Water Absorbed and Adsorbed by Clay Grains

The first portion added would be absorbed by the grains to satisfy their porosity. The next portion added would spread itself evenly over the surfaces of the clay material, and this with the water imbibed by the particles (when the thus wetted particles are brought into contact), forms a system of what may be properly termed capillary water, spreading itself in all directions throughout the mass, and forms the medium through which the attractive forces operate to bring the mass together; an action not unlike that of a water film between two glass plates. Assuming flexible plates roughened by etching or sand-blasting to simulate the irregularity of the clay particles, the parallel becomes more complete. Careful measurement shows the glass plates a little closer together when held by a water film than when dry. The writer, attempting to measure the thickness of this film between superimposed pieces of plate glass, found the pile appreciably shorter when wetted than when measured dry. A similar situation must obtain in the action of the film between the clay particles.

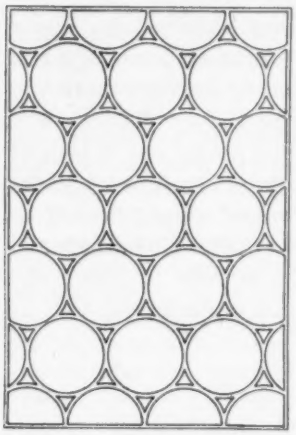

FIG. 1.—Clay mass at its maximum density showing the capillary and filler water systems, the latter shown by the triangles. At this stage there can be no general movement of water to the surface.

The mass at this stage of water content is at its maximum density; any addition or removal of water should cause an increase in volume. This no doubt accounts for the increase in volume which is found in pats of de-aired clays toward the end of the drying period.

Whereas this system is a water carrier it is only more or less efficient as such, for it can act only when the mass is in a rigid condition such as it is at this stage of water content, and when connected to a free moving water supply. Thus on account of the low water content of the mass at this stage of drying, together with the higher temperatures which obtain at this time which would cause capillarity to diminish, coupled with the improbability of any great number of sources of supply, capillarity plays a rather unimportant part in the drying process.

Wetted Clay Particle as a Bubble

It may be of interest to venture for a moment into the more obscure action of this film between the clay particles. We can very properly regard a wetted clay particle as a clay-filled bubble. We know that the tendency of these films is to economize in area. For this reason soap bubbles and drops of water are round, while those of a single plane surface will move loads in their tendency to shrink. They possess energy. This energy in a soap bubble may be shown by directing the open tube to the flame of a candle. The bubble will contract forcing the air out sufficiently to deflect the flame. It is evident that if this bubble or film was within another, the two would give twice the energy. Each enclosing film would add its share of energy toward a common center.

On bringing soap bubbles together into a system of bubbles or suds there is a new alignment of forces, as the system inclines to the spherical, each bubble sacrificing some of its characteristics to the system. Each bubble becoming a segment or member of a larger double walled hollow sphere enclosing smaller spheres of the same character. The whole resulting in a series of concentric or nested bubbles. These nested bubbles are separated by the air contained in the original bubbles but held together by the water films at their points of contact. In this nested form the combined energy of the whole is directed upon a common center. The forcing of this spherical mass into other shapes or forms cannot affect its nested character.

Why Shrinkage is to a Common Center

If a wetted clay particle may be regarded as a clay-filled bubble, it follows that the clay mass at this stage of water content may also be regarded as a bubble mass where the forces strive to align themselves in the same fashion as in the soap bubble system, with this difference—in the soap bubble system the air pockets conform to the film, while in the clay mass the film must adjust itself to the clay particle. Except for the fact that not quite so perfect spheres are formed in the latter, the cases are parallel. In each, we have the same nested system directing their forces upon a common center. In the clay mass with its almost infinite number of these films, together with an enormous number of the contact points, both of which cause forces acting concentrically, we can begin to realize the tremendous energy stored within a wetted clay mass. Regarded in this light we get a rather clear reason why clay shrinkage is toward a common center.

Pore Water

The irregular shape of the clay particles results in many void spaces. The next portion of the water which we would add would just fill these spaces forming a more or less complete system of connected pools

of varying shapes and sizes. This system is not a water carrier, in the sense that the water would find egress through it to the surface. The mass still being in a rigid condition, incapable of shrinkage or other readjustment, a general movement of this water would result in a vacuum within the mass. A movement of this water cannot, therefore, take place. Thus this so-called pore system has no part whatever in surface replacement during drying; it is merely a filler.

Water of Mobility

To give the mass flowing qualities as demanded by the plastic processes, a final addition of water is necessary. The introduction of this water, which must be accomplished by force, necessarily causes a wedging apart of the previously wetted clay particles, which in turn results in an increase in volume of the mass. Thus a third system of water, rather layerlike in character, criss-crossing in all directions in uniform area, is produced, crooked slightly, or divided when a clay particle interferes, but maintaining a straight course across intervening pools of filler water. These layers or channels, due to the attractive forces operating within the mass, present their outer terminals to the surfaces in beadlike protuberances, like water above the rim of an overfilled vessel. This is the major water carrying system, in fact the only system in operation during the shrinkage period of drying. Thus the size of the water carrying channels is purely a function of the water of moldability. Their areas or thickness can only vary with the amount of this portion of water added. Thus while they may be "fine" or "coarse" their length depends entirely upon the shape and size of the mass.

It becomes evident too that the wedging apart of the previously wetted clay particles results in the breaking up of the previously formed capillary system. For instead of a continuous system which obtains before the introduction of the final portion of water, the capillary film is now confined to the surfaces of the individual grains. Thus in no case can the capillaries draw from a greater depth than the thickness of the clay particles at the surface of the piece. The breaking up of the capillary system while impairing its efficiency does not altogether destroy it. In a lesser degree only do we have the same attractive forces at work in the same manner and direction as under the discussion of capillary water. The members of the mass at this stage, except as affected by gravity, are in a state approximating perfect suspension, the whole being enclosed and a part of an ideally contractile, concentrically acting system of forces which in the nature of things must promptly respond to any change in equilibrium between the forces operating within the mass and the tension at the surface bringing with them the enclosed and attached clay particles.

The Physics of Water Removal

It thus becomes increasingly evident that water replacement to the surface during drying cannot be due to capillarity, that is, in the sense that the shrinkage water channels act as capillary tubes. Not only do the capillaries or films lack the necessary continuity to the surface, but also because of the fact that so long as the particles which must compose the walls of those tubes are free to contract, the attractive forces will expand themselves not in raising water, but in the bringing together of the walls, thus squeezing the water from between them; an action, which but for the surface tension operating upon the outer terminals of the channels, would force the water of moldability from the mass.

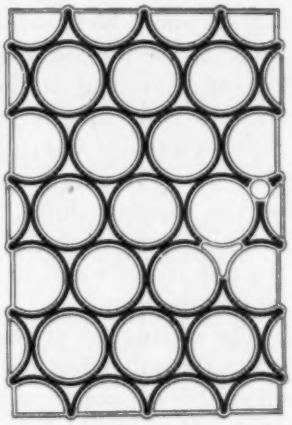

FIG. 2.—Clay mass at the stage of moldability. Capillary films shown by the thin light bands. Filler water by triangles. Water of mobility by heavy lines, while to the right are shown the closing effect of occluded air blebs. Note the capillary films are now confined to the clay particles, except at points where the air blebs make possible their continuity to the surface. In this case only, do they become water carriers during the shrinkage period.

However, as soon as the walls are brought together, which would coincide with total shrinkage, the continuity of the capillary system is again established and capillary movement would again become operative as outlined above and the rate of water loss begins to decrease. Thus in any case, it is not until all danger from cracking has passed, that there is even a possibility of the laws governing capillarity becoming applicable.

We avoid much difficulty in accepting the idea of a squeezing action within the mass, which, instead of giving us enormous resistances which do not show in our experimental drying curves, gives us almost infinite forces to compensate for the constantly narrowing channels during the shrinkage period. We are thus enabled to nicely account for the substantially identical rates of water loss, regardless of the size of the channels.

Inasmuch as these forces must diminish as the temperature rises, and vanish when the distinction between the liquid and its vapor ceases, we should expect the rate of water diffusion to be higher at the beginning of drying, than later when the piece becomes heated through. There is just a hint of this in an occasional drying curve, where the drop is a little more rapid during the first hour or so than during the remainder of the shrinkage period. It is to be hoped that someone who is in a position to do so will clear this point by careful experiment.

Air as Cause for Drying Cracks

Since it is while expelling the water of moldability that losses from cracking occur the cause must be in the functioning of the channels. Since there is nothing in a simple mixture of clay and water which would prevent the proper drainage of these channels, we would naturally look for some extraneous cause for the phenomena.

Clays which have been tempered and pugged in contact with air of necessity contain quantities of occluded air. Some of this air will be small blebs which have no effect on the drainage conditions. Most of the air, however, will be in pockets of a larger volume than can be contained in the filler water cavities and encroach upon, or entirely close up the channels formed by the water of moldability, thus effectually shutting off the flow of any water through them. (Fig. 2). These larger blebs regardless of their size can have no effect on the capillary films. Thus while egress to the surface is not entirely cut off by the action of the air bleb, the carrying capacity of the film is not equal to the requirements of evaporation and rupturing strains develop.

The closing up of the major water carrying channels by the blebs is not the only effect produced by them. We must also reckon with the inevitable expansion of this air which takes place under the heat of the drier. Here the blebs are not only expanded in volume with a further choking effect, but the pressures generated often are of sufficient force to cause ruptures even in saturated atmospheres where no drying whatever takes place. This is probably a very frequent cause of breakage among the fine grained, feebly plastic types.

Then again the presence of air within the clay mass has a serious effect upon its strength. It is possible to almost entirely neutralize the effect of plasticity by working air into the mass. Add to this the closing effect of the blebs and the expansion under heat of the drier and we have no difficulty in explaining drier losses.

The more plastic or tighter the clay, the greater the effect of a given quantity of occluded air upon the water carrying channels, and the less the opportunity for the air to escape from the mass. On the other hand, the more open the clay, the less a given quantity of air would affect the drainage system, and the easier would be the escape of the air through a more complete and less resistant pore system.

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PROPERTIES OF SILICA BRICK FROM COKE OVEN WALLS[1]

By Sandford S. Cole[2]

ABSTRACT

Silica shapes from coke ovens were tested to see what change had occurred after long service. Brick from Chicago and Birmingham districts were examined. Chemical analyses: specific gravity, porosity, fusion values and petrographic examinations were obtained on the samples.

Introduction

Silica brick from the walls of open hearth steel furnaces have been studied by several investigators. V. P. Sokolov[3] in a report upon silica brick used in Martin furnaces claimed the formation of asmanite instead of tridymite. A discussion in an anonymous article[4] gave reasons for the changes occurring in silica brick from an open hearth furnace. C. S. Graham[5] reported analyses made on silica brick from a basic open hearth according to the color zones formed in the brick. An examination was made by M. Meredith[6] and also by J. E. Stead[7] of brick from the roof of an open hearth. H. Thomas, A. Hallen and E. Rodley[8] gave analyses and photomicrographs of silica refractories from a furnace. D. W. Ross[9] examined silica brick from a glass furnace and found tridymite and calcium monosilicate formed on the interior, with the exterior of cristobalite and quartz. The first work, where slag did not come in contact with the silica, was done by A. A. Klein and L. S. Ramsdell[10] upon brick from a tunnel kiln. The quartz was found to be converted to a large extent to tridymite. W. J. Rees'[11] photomicrographs of various sections of a silica block from an open hearth furnace showed the conversions which had occurred. In the work previously reported the formation of tridymite seems to occur on the hot face of the brick. A partial conversion of the cristobalite to tridymite, and a nearly complete conversion of quartz to cristobalite and tridymite occur in the hotter zones.

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[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (White Wares Division.) Recd. Dec. 28, 1925.

[2] Industrial Fellow, Koppers Co. Laboratories, Mellon Institute, Pittsburgh, Pa.

[3] Zapisti Imp. St. Petersburg, *Mineral Obshch.*, **44**, 473 (1908).

[4] *Soc. Chem. Ind.*, **29**, 880 (1910).

[5] *Iron and Coal Trades Rev.*, **102**, 639 (1918).

[6] *Can. Machy.*, **31**, 167 (1919).

[7] *Trans. Ceram. Soc.* (Eng.), **18**, [2] 384–87 (1919).

[8] *Brit. Geol. Survey*, **16**, 115 (1920).

[9] *Jour. Amer. Ceram. Soc.*, **4**, 65–67 (1921).

[10] *Ibid.*, **4**, 805 (1921).

[11] *Ibid.*, **8**, 40 (1925).

Purpose of the Present Investigation

Very little study has been made of silica brick from coke oven walls. In this investigation, the two samples of brick examined came from different manufacturing districts and had been used in two types of furnaces. The purpose of the examination was to determine the general condition of the silica brick after use. The brick had been in service for the same length of time and were located in the same relative positions in the oven walls. However, variations in test results after service might be expected, since the brick were made of different ganisters and had doubtlessly been subjected to different operating conditions.

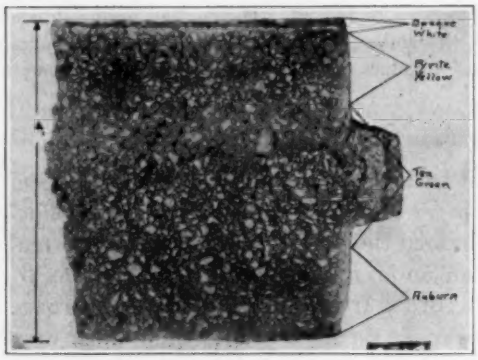

FIG. 1.—Cross-section of a silica shape used in construction of Semet-Solvay ovens for By-Product Coke Corp., S. Chicago, Ill.

Description of Samples

The first shipment tested consisted of brick produced from Baraboo ganister in the Chicago district. They had been used in a horizontal flued oven with an operating temperature probably up to 2650°F. These samples were assigned letters A, B, and C. The second set of brick had been made from Alabama quartzite in the Birmingham district and had been used in a vertical flued oven with an operating temperature probably up to 2600°F. They were assigned letters D, E, and F. Both samples of brick had been in service for twelve years under constant operation.

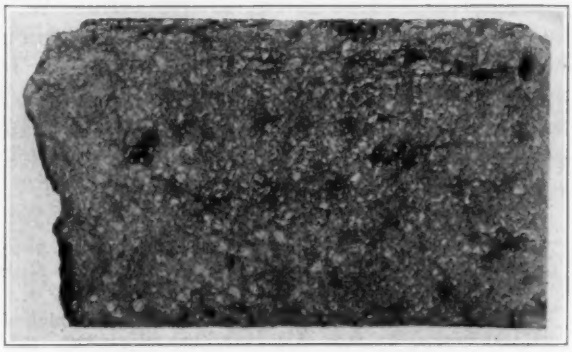

FIG. 2.—Cross-section of Sample C.

The Chicago district shapes will be described first.

Sample A was a 4-inch block used in the oven wall with one surface

exposed to the coal. The block had been placed in the oven in 1912 and removed in 1924. It was located 4 feet above the floor and 3 feet from the coke side end of the oven. Figure 1 shows a broken cross-section of the shape with the various colored bands indicated.[1]

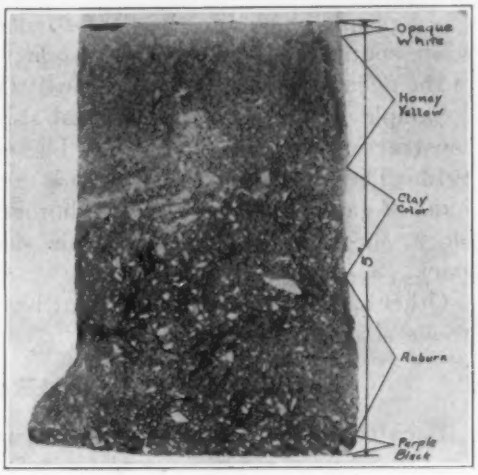

FIG. 3.—Cross-section of a silica shape used in construction of Woodward Iron Company, Battery No. 2, Brand 74–L.

Sample B was a block 2 inches thick used as an inside brick for the flue and was not exposed to the coal. There were two sections to this sample. The face exposed to the flame was opaque glass for $\frac{1}{8}$ inch. The balance of the shape was clay color with white spots scattered through this portion. This brick was placed in the oven in 1915 and was 4 feet from the floor and 3 feet from the coke side of the oven.

Sample C was the same shape as Sample A, but had not been used. This block was part of the original shipment made in 1912. It was straw color with gray and white spots scattered through the brick. The size of grain to which the ganister had been ground is shown by a section of the brick, Fig. 2.

FIG. 4.

The Birmingham district samples are next described.

Sample D was a liner block used in the flue wall and was 5 inches thick. A section of this brick is shown in Fig. 3. This shape was located 2 feet 6 inches from the floor and 7 feet 6 inches from the coke side

[1] The colors referred to in describing the brick were obtained by comparing the samples with a color chart in "Color Standards Nomenclature," by Robert Ridgway.

end of the oven. This shape was placed in the oven in 1913 and removed in 1925.

Sample E was another liner block located 4 feet 3 inches above Sample D in the same flue wall. The first $\frac{1}{8}$ inch from the coal side was a purple black and the next 4 inches were a clay color with some white spots. The last inch was a honey color. This shape was placed in the oven in 1913 and removed in 1925.

Sample F was from the original shipment of shapes for the oven construction but was not used. These shapes were manufactured in 1913. The interior of the piece was cream color with gray and white spots of ganister. Figure 4 is a photograph of a broken section of the block, showing the spots and grain size. This piece was five inches thick.

Other samples were obtained but have not been described since the above shapes are representative.

Tests Performed and Results Obtained

Each colored zone was sampled separately and tested for:

1. Fusion
2. Apparent specific gravity
3. Per cent porosity
4. True specific gravity
5. Microscopic examination
6. Chemical analyses

The results obtained on the samples are as follows:

Sample No.	Section tested	App. sp. gr.	Per cent porosity	True sp. gr.	Fusion	Microscopic examination
A	Coke side 1½"*	2.319	20.93	2.321	31	Tridymite Cristobalite
	Flue side 1–2"	2.289	20.92		31	Tridymite Cristobalite
	Flue side ⅛"			2.294	31	Tridymite
B	Flue side 1"	2.288	21.0		30–31	Tridymite Cristobalite (slight)
	Wall side 1"	2.317	21.2		30–31	Cristobalite Tridymite
	Flue side 1½"			2.327	30–31	Cristobalite Tridymite
	Flue side ⅛"			2.282	31	Tridymite
C	Center	2.340	21.88	2.350	31–32	Quartz Cristobalite Tridymite(slight)

* The distance was that measured from coke or flue side and sample was from that section contained in these limits.

Sample No.	Section tested	App. sp. gr.	Per cent porosity	True sp. gr.	Fusion	Microscopic examination
D	Flue side ¼–2½″				32	
	Flue side 1–1½″	2.284	25.51	2.309		Tridymite Cristobalite
	Coke side ¼″			2.298	30–31	Tridymite Cristobalite
	Coke side 1″	2.304	22.6	2.333		Cristobalite
	Flue side ⅛″			2.295	32	
	Coke side ¼–2″				32	
E	Center	2.275	22.42	2.287	31–32	Tridymite
F	Center	2.325	22.31	2.317	32	Quartz Cristobalite Tridymite

Various sections were analyzed for chemical constituents. The Al_2O_3, Fe_2O_3, CaO and MgO contents were determined by analysis but the SiO_2 values indicated were obtained by difference.

	A ¼–1 in. from flue side	A 1–2½ in. flue side	A ¼–1½ in. coke side	C Center
SiO_2	95.45	95.28	95.25	95.97
Al_2O_3	1.31	1.16	1.22	0.98
Fe_2O_3	0.91	1.16	1.12	0.95
CaO	2.25	2.32	2.32	2.00
MgO	0.08	0.08	0.09	0.10
	100.00	100.00	100.00	100.00

	D ¼ in. flue side	D ¼–2¼ in. flue side	D ¼ in. coke side	D ¼–2 in. coke side	F Center
SiO_2	96.62	96.48	93.77	96.16	96.19
Al_2O_3	1.12	0.67	2.56	0.80	1.01
Fe_2O_3	0.40	0.89	2.02	0.99	1.71
CaO	1.64	1.73	1.40	1.80	1.87
MgO	0.22	0.23	0.25	0.25	0.22
	100.00	100.00	100.00	100.00	100.00

Discussion of Results

The specific gravity values justify the assumption that the silica has been largely converted to tridymite during use. The original sample from the Chicago district contained unconverted quartz, but the specific gravity shows a change to tridymite and cristobalite. This was confirmed by the microscopic examination. The porosity has been little changed and the fusion point only slightly lowered. The

chemical analyses show a slight increase in R_2O_3, probably due to coal ash coming in contact with the walls. The same difference was found in the silica brick from the Birmingham district. Long heat service causes the quartz to be converted to tridymite or cristobalite in the hotter or cooler zones of the brick. The increase in R_2O_3 is very definitely shown in the analysis of the $\frac{1}{4}$-inch coke side of Sample D. This sample was from the face of the shape next to the coal where the silica has combined chemically with the ash in the coal. This is well shown by the change in color of the silica on the surface of the brick. The face of the brick next to the flue was reduced in Fe_2O_3 content but increased in Al_2O_3 and in SiO_2. The color of the silica from both districts was about the same after the same length of service. The chemical changes were very slight except on the faces of the samples.

The unused brick showed quartz, cristobalite and tridymite in the mass. The amount of tridymite in Sample A was not as large as in Sample D. The silica at the flue face was practically completely converted to tridymite and the cristobalite increased as the cooler face was approached. In the case of Sample D "coke side 1" an occasional grain of quartz was found surrounded by cristobalite. This section evidently had not been heated to a high enough temperature to cause a complete inversion. The change of quartz to cristobalite and tridymite must have occurred at temperatures of 1000–1300°C since the coal face of the oven wall would not ordinarily exceed 1300°C. Evidently long time or a catalyst has bought about this change in the structure of the silica.

Summary

The following general conclusions have been reached:

1. Silica brick made from different quartzites have like properties after long service.
2. Very little change in chemical composition occurred.
3. Very slight change in porosity resulted.
4. The long service has brought about a conversion of the quartz to cristobalite and tridymite. On the flue face of the brick chiefly tridymite was present while on the coke face cristobalite was predominant.
5. The silica brick were in good condition after twelve years of continuous service at operating temperatures probably as high as 2500-2600°F. The only vitrification which had occurred was a glazed surface on the flue face.

The author wishes to acknowledge the assistance which J. A. Shaw has given in determining the analyses of the samples.

CHEMICAL COMPOSITION OF WINDOW GLASS[1]

By Edwin P. Arthur

ABSTRACT

The compositions of window glasses manufactured by various methods are compared. The tendency of glass to devitrify and ways of overcoming this are discussed, using diagrams based on the work of Morey and Bowen to illustrate the various points.

The ideal window glass composition, of course, is that one which will meet the market demand and which can most readily be manufactured at a profit. The manipulation of machinery used to make sheet glass permits some variation in the chemical composition. The glass forming machine, however, cannot accommodate variations in physical characteristics as did the workmen who made window glass by "hand." Consequently a much more uniform melt is required for best operation of the glass making machines than was ever necessary for "good glass" in a "hand plant."

One of the prime requirements of window glass is durability, stability or resistance to weathering. Gelstharp and Parkinson[2] have pointed out the possible composition of glass of three components SiO_2, CaO, and Na_2O on the basis of durability. The composition limits are indicated in the triaxial diagram (Fig. 1) by the shaded area. It is understood that minor constituents such as iron, alumina in small quantity, sulphates, chlorides, etc., would affect the behavior of commercial glass to some extent.

Method of manufacture	1 Hand-made	2 Lubbers	3 Slingluff	4 Colburn	5 Fourcault
SiO_2	71.9	74.3	73.1	72.8	73.8
CaO, MgO	14.2	12.6	14.2	13.1	11.1
Na_2O	13.9	13.1	12.7	14.1	15.1

The number dots within the shaded area in Fig. 1 refer to the table, which shows the approximate composition of five window glasses manufactured in different ways. The percentages in the table were calculated from typical analyses of glasses by deducting the total of minor constituents from 100% and recalculating the percentage of silica lime and alkali of the remainder. The best present practice

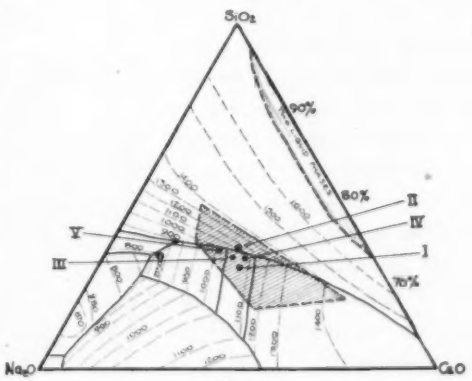

FIG. 1

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb. 1926 (Glass Division). Received January 8, 1926.

[2] *Trans. Amer. Ceram. Soc.* **16,** 109 (1914).

for window glass composition would seem to fall in a rather limited field. The different glasses are, nevertheless, distinct from each other as the glass making machines are sensitive to a surprising degree.

One of the principal manufacturing difficulties, especially with the Colburn and Fourcault machines, arises from a tendency of the glass to devitrify. If glass is cooled to reach a proper viscosity for working, some component of the melt may crystallize introducing opaque masses into the sheet thus forming highly objectionable defects.

Recent work of Morey and Bowen[1] is extremely interesting in this connection. They determined the crystallizing points of the three component system SiO_2, CaO, Na_2O by a series of fusions and quenchings employing special technique for accuracy. Their results, shown in Fig. 1, set the temperature limits very definitely beyond which devitrification will take place, disregarding the effect of minor constituents which may be in commercial glass as above.

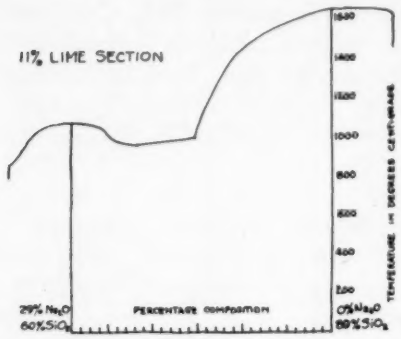

FIG. 2

In Fig. 2 is shown a two-component section through the Morey-Brown diagram at the line of 11% CaO. It is readily seen that the composition for a durable glass which can be cooled to the low point without devitrification is about 15% Na_2O and the minimum temperature about 1000°C, facts entirely confirmed by practice. For example, such a glass as mentioned will work well at 993°C while a variation of 10° is known to cause considerable difficulty. It is seldom that the results of so-called pure research so exactly coincide with practice. The many factors entering into large scale operation often vitiate or mask the most thoroughly accurate work of this character.

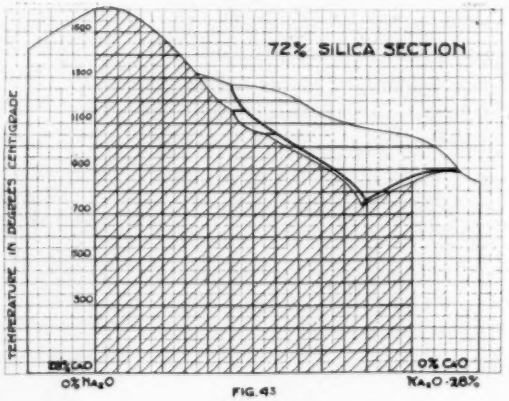

FIG. 3

A two-component section at 72% SiO_2 is shown in Fig. 3. A glass such as

[1] *Jour. Soc. Glass. Tech.* **9**, 226 (1925).

the hand made window glass No. 1, containing 14% CaO and 72% SiO_2 is generally worked and quickly cooled from temperatures near 1150°C (2100°F). This temperature is well above the crystallization point, a fact which explains the absence of devitrification troubles in making hand blown glass.

The author wishes to acknowledge helpful criticism of James R. Withrow of the Department of Chemical Engineering, Ohio State University, and aid of W. H. de Bruin in preparation of drawings.

COLUMBUS, OHIO.

THE HEAT REQUIRED TO FIRE CERAMIC BODIES[1]

By A. Ernest MacGee[2]

ABSTRACT

A differential thermal method for determining interval specific heats of ceramic materials is described. The specific heat of the unknown is determined by comparing its temperature to that of quartz after each sample has been subjected to a definite heat treatment. This method shows the number of calories required to heat one gram of the material in question from 0 to t°C, accounting for all thermal processes which the material may undergo during the heating process. It shows the temperatures at which the various thermal processes begin and end as well as the quantitative figures for the more pronounced of these thermal processes.

The kaolin, ball, flint, and diaspore clays undergo an endothermic reaction at about 575°C which amounts to "60 to 130" calories per gram of the air dried material. They undergo an exothermic reaction at about 960°C which amounts to about 25 calories per gram of the air dried material. About 510 calories are required to heat one gram of any firebrick body from 25 to 1200°C, the specific heat over this interval being about .43. About 500 calories are required to heat one gram of any kaolin or ball clay from 0–1000°C, the specific heat over this interval being about .5. About 290 calories are required to heat one gram of flint or feldspar from 0–1050°C, the specific heat over this interval being about .28.

Instead of the kiln efficiencies being about 22% as was previously believed, this work proved them to be about 35%.

Introduction

1. Purposes of Investigation

The present investigation was undertaken with the object of ascertaining the number of calories necessary to heat a given mass of a ceramic body to any given temperature. This involved the determining of the interval specific heats of the various materials. By interval specific heat is meant the number of calories per degree which must be added from some external source in order to raise the temperature of one gram of material from 0 to t°C.

The determination of the interval specific heats of most ceramic materials is greatly complicated owing to the fact that they often undergo thermal changes on heating which are not reversed on cooling, such as the decomposition of carbonates, sulphates, hydrates, etc. In addition to the thermal processes accompanying the various chemical reactions, there are often physical reactions that involve thermal changes, such as the transformation of one allotropic modification into another, the latent heat of fusion, and the solution of solid constituents

[1] This investigation was carried out coöperatively by the U. S. Bureau of Mines and the Ohio State University Engineering Experiment Station, and the data herein given has been presented through the Department of Ceramic Engineering to the Graduate School at the Ohio State University as a thesis in partial fulfillment of the requirements for the Doctor's degree. Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (General Session.) Received January 12, 1926.

[2] Research Engineer, U. S. Bureau of Mines.

by a melt. F. Richars[1] has pointed out that the specific heat near the fusion point is abnormally high, being due to the fact that, to a great extent, the latent heat of fusion is involved. Furthermore, many ceramic materials such as the clays contain combustible matter which is fired out during the firing process. Therefore, air must be in free contact with the sample under test so as to permit this combustion to take place. Any method employed for the determination of the interval specific heats of ceramic bodies must be of such a nature as to account for any and all thermal changes which the material may undergo in heating. This is true because the amount of heat required to be added to heat a given body to a given temperature is dependent upon the net result of all endothermic and exothermic reactions which the material undergoes during the heating process. Since none of the methods previously employed accounted for all of these various thermal processes, it was necessary either to revise one of the old methods or develop a new one. A method was developed which, it is believed, covers all of the conditions underlying interval specific heat determinations when applied to materials which undergo irreversible thermal changes. In addition to determining the number of calories required to heat a given weight of material to t degrees centigrade, it was possible to derive the actual quantitative values for the more pronounced thermal processes which the material undergoes. Also, the temperatures at which the reactions take place are plainly discernible.

2. The Problem of Heat Economy

The problem of heat economy in the ceramic industries is, quite obviously, of very great importance because of the large consumption of fuel in the drying and firing operations, ranging from 10 to 30% of the total cost of production in the different industries. Anything that would lead to a lessened fuel consumption would greatly benefit the ceramic industries. A variety of drier and kiln constructions, such as the tunnel car and continuous kilns, has been designed to obtain greater economy of fuel. Recommendations for improving the designs of kilns and firing methods can be scientifically made only when the fundamental data, such as thermal conductivity, specific heat, convection, radiation, and heat distribution, which are connected with the drying and firing operations, are known. Much of these essential data, especially interval specific heats, is lacking.

A. V. Bleininger[2] conducted an investigation to ascertain the distribution of heat in several ceramic kilns. This investigation covered four different kilns, two of which were firing terra cotta; the other two were

[1] "Die Theorie des Gesetzes von Dulong und Petit," *Z. f. Anorg. Chem.*, **59** (1908).

[2] "A Study of the Heat Distribution in Four Industrial Kilns," *Trans. Amer. Ceram. Soc.*, **10**, 412–49 (1908).

firing paving brick and sewer pipe respectively. The heat required to heat one gram of a clay containing 2% of hygroscopic and 7% of chemical water from 20 to 1120°C was calculated to be distributed as follows:

Used in driving off hygroscopic water	12.1 cal.
Used in driving off chemical water	23.1 cal.
Used in heating dry clay (sp. ht. assumed to be 0.2)	204.6 cal.
Total	240.8 cal.

From considerations similar to these it was determined that of the total heat inducted into the kilns 5.71% was used to heat the sewer pipe, 11.3% to heat the paving brick, and 12.51% and 8% respectively of the total inducted heat was used to heat the terra cotta.

During the years 1922 and 1923, the U. S. Bureau of Mines[1] investigated the heat used in several types of kilns employed in firing refractories. This investigation involved an extensive series of experiments which were conducted in the respective factories under actual operating conditions and furnishes, therefore, an interesting and significant insight into the actual distribution of heat during the firing process. The utilization of heat was found to be distributed among several sources as follows:

1. Heat used to raise the temperature of the brick to the finishing temperature (calculated from an interval specific heat of about 0.26).
2. Heat used to evaporate the water from the ware.
3. Heat lost as combustible matter in the ash.
4. Heat lost as combustible matter in the flue gases.
5. Heat lost in dry flue gases.
6. Heat lost in water vapor in flue gases derived from coal.
7. Heat used to raise the temperature of the walls of the kiln.
8. Heat used to raise the temperature of the crown of the kiln.
9. Heat lost by radiation and convection from the crown and walls of the kiln.
10. Heat given up by gases between the bottom of the kiln and the stack.

The quantitative distribution of the heat as calculated from the experimental data is shown in Table I.

Since in many cases, the unaccounted for losses of heat go as high as 20%, it is apparent that there is room for a substantial increase in the accuracy of some of the experimental data from which the values for the distribution of heat was calculated. The value used as representing the interval specific heat of the fire brick was about 0.26. This value represents the specific heat of the fired brick and is, in all probability, entirely too low for the green brick. The interval specific heats of the green brick were determined by the method employed in this investiga-

[1] W. E. Rice and R. A. Sherman, "Determination of the Distribution of Heat in Kilns Firing Clay Wares," *Jour. Amer. Ceram. Soc.*, **7**, 738–63 (1924).

tion and found to be about 0.43 over the interval 0–1100°C. This obviously greatly reduces the unaccounted for heat losses and materially increases the efficiency rating of the various kilns.

Thus, one sees that only a portion of the heat produced by the fuel is utilized in actually heating the ware to its maturing temperature. If the interval specific heat of the material to be fired is known, the amount of heat actually required to heat it to its maturing temperature can be readily calculated; that is, the efficiency of a kiln operation can be accurately determined simply by knowing the calorific power and quantity of fuel consumed in heating the kiln of ware of known interval specific heat to its maturing temperature.

3. Methods for Determining Specific Heats

The procedures which have been employed in the past to determine the specific heat of a given material can be classified under one or more of the following general methods:

(*a*) From calculations based upon the law of Dulong and Petit and which require no experimental determinations. This law states that the product of the specific heat and the atomic weight of the solid elements is constant, being approximately 6.4.

(*b*) From data obtained by a method based on Newton's law of cooling, which states that the time taken by equal masses of substances under exactly identical conditions in cooling through equal ranges of temperature is directly proportional to their specific heats.

(*c*) From data obtained by the procedure known as the method of mixtures. This involves heating the weighed unknown to the temperature in question and allowing it to fall into a calorimeter. Thus the quantity of heat it contains at the time of dropping can be measured and its specific heat calculated.

(*d*) From data obtained by measuring the electrical energy required to heat the sample to a given temperature, the current passing through the test piece. This method is, unfortunately, limited to conductors of the first class and is thereby inapplicable for measuring specific heats of ceramic materials.

(*e*) From data obtained by measuring the energy required to bring the material, contained in a calorimeter, to a given temperature. Griffiths and Griffiths[1] were probably the first to measure the heat required to elevate a sample to a given temperature by noting the electrical energy consumed in the process. Thus knowing the number of calories absorbed by a given weight of sample in heating it to t°C, its specific heat is readily calculated. They used a twin calorimeter, one of which contained the sample. The calorimetric method in one modification or another, has been used by many investigators for ascertaining specific

[1] Griffiths and Griffiths., *Phil. Trans. Roy. Soc. of London*, **A213**, 119 (1913).

TABLE I

HEAT ACCOUNTS OF REFRACTORY KILNS

Type of kiln	Inside dimensions (feet)	Number of furnaces	Grates	Number of stacks	Ware	Pounds of coal per thousand 9-in. equiv. for a no. of preceding firings	Test	Test serial number	Duration in hrs.	Final temp. in °F	Pounds of coal per 9-in. equiv.	Tons of coal per T. of ware	Per cent total heat in coal fired
Round down-draft	20	10	Horizontal	1	Fire clay	——	*A*	1	149½	2140	1270	0.20	100.0
							B	2	117	1980	1390	0.22	100.0
Rectangular downdraft "Newcastle"	30½x16½	6	Horizontal	1	Fire clay	1875	*A*	3	156	2140	1730	0.25	100.0
							B	4	134½	2230	1700	0.24	100.0
Round down-draft	30	12	Sloping	1	Fire clay	2180	*A*	5	206½	2160	1940	0.28	100.0
							B	6	129	2210	1510	0.22	100.0
Round down-draft	28	8	Sloping	1	Fire clay	1200	*A*	7	154½	2110	980	0.14	100.0
							B	8	114	2220	1070	0.15	100.0
Round down-draft	25	10	Dead bottom	1	Fire clay	1513	*A*	9	83½	2150	1420	0.20	100.0
							B	10	80	2100	1370	0.20	100.0

TABLE I (*concluded*)

HEAT ACCOUNTS OF REFRACTORY KILNS

Heat used to raise the temperature of brick	Heat used to evaporate moisture from brick	Heat in combustible ash	Heat in combustible flue gases	Heat in dry flue gases	Heat in water vapor in the flue gases formed from coal	Heat used to raise the temperature of the walls of the kiln	Heat used to raise the temperature of crown of kiln	Heat lost by radiation and convection from the walls of the kiln	Heat lost by radiation and convection from the crown of the kiln	Heat given up by gases between bottom of kiln and stack	Unaccounted for losses obtained by difference	Test serial number	Unaccounted for losses obtained by difference using specific heat values obtained in this investigation
Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent		
19.4	3.5	7.5	1.5	27.4	5.0	15.3	3.9	2.2	0.7	5.6	8.0	1	— 4.7
15.7	3.2	6.8	0.0	24.8	4.7	12.3	3.0	1.2	0.5	13.0	14.8	2	4.3
16.5	0.4	6.3	0.3	31.0	5.5	6.0	2.1	2.9	6.5	11.9	10.6	3	0.3
17.3	0.4	5.0	0.6	31.1	5.5	6.9	2.1	1.9	5.5	7.5	16.2	4	4.9
16.6	1.4	4.2	5.3	19.3	6.1	5.5	2.1	1.0	4.4	10.7	23.4	5	13.1
23.6	1.6	4.2	2.1	18.3	6.1	7.3	2.8	0.5	4.0	6.7	22.8	6	8.2
26.3	2.0	3.6	0.5	20.4	4.7	8.2	3.1	2.0	4.4	12.2	12.6	7	— 3.5
27.7	2.0	4.7	0.3	18.8	4.9	8.2	3.4	0.7	3.8	12.3	13.2	8	— 3.3
23.8	1.2	4.5	0.5	21.2	5.6	6.7	3.6	1.2	1.0	12.0	18.7	9	5.2
22.0	1.0	6.4	0.6	18.5	5.4	6.8	3.4	0.5	0.7	5.1	29.6	10	17.0

heats and thermal reactions which a sample undergoes during a heating process.

(*f*) From data on heat required to bring the material to a given temperature, calculated from curves obtained by a differential thermal method.

Previous Investigations

Joseph Black[1] was probably the first to illustrate the different capacities for heat of the same mass at different temperatures. The work of Black was continued by Irvine[2] who was the first to publish a clear explanation disentangling the four entities, specific heat, mass, temperature change and quantity of heat, when more than one was varied at a time. This work was conducted about 1770, and from then on the scientific world has had a clear conception of the phenomenon which enables different substances and the same substance at different temperatures to absorb different quantities of heat. The work of Irvine was followed by that of Laplace and Lavoisier.[3] Although Crawford[4] was probably the first to use the method of mixtures, Dulong and Petit[5] employed it to make the first really accurate specific heat measurements and, as a result of their determinations, formulated their well-known law. This work was followed by that of Potter,[6] Regnault,[7] Richards and Frazier[8] and others. Wilson, Holdcroft and Mellor[9] determined the specific heat of fire brick by a modification of the method of mixtures and found the average value to be 0.261 at 1150°C. They found that the specific heat equals $.193+.00006\,t$. Doughill, Hodsman and Cobb[10] found the specific heats of fireclay brick and silica brick to be 0.26 and 0.27 respectively at 1000°C. These values agree quite favorably with those of Bradshaw and Emery[11] who found the specific heats of Stourbridge fire brick and silica brick to be 0.263 and 0.262 respec-

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[1] J. Robinson, "Lectures on the Elements of Chemistry," edition of 1807, Philadelphia; p. 81. Note 1 by Robinson, p. 330.

[2] Irvine, "Essays, Chiefly on Chemical Subjects," London, 1805.

[3] Memoirs de L'Academie de Science, 355 (1780), Oeuvres de Lavoisier, II, 287, 724 (1862).

[4] Experiments and Observations on Animal Heat, London, 1777–78.

[5] *Ann. de Chem. et de Phys.* [2], **7,** 142 (1817); *Ann. de Chem. et de Phys.* [2], **10,** 395 (1819); *Jour. Ecole Polytechnique*, **11,** 189 (1820).

[6] *Edinburgh Jour. Sci.* (New Series), **5,** 80 (1831); **6,** 163 (1832).

[7] *Ann. de Chem. et de Phys.* [2], **73,** 5 (1840); *Ibid.* [3], 322 (1843); etc.

[8] *Chem. News*, **68,** 84 (1813).

[9] "The Specific Heat of Fire Brick at High Temperature," *Trans. Ceram. Soc.* (Eng.), **12,** 279–84 (1912–13).

[10] "The Thermal Conductivity of Refractory Materials," *Jour. Soc. Chem. Ind.*, **34,** 465–71 (1915).

[11] "Specific Heat of Refractory Materials at High Temperatures," *Trans. Ceram. Soc.* (Eng.), **19,** 84–92 (1919–20).

tively at 1000°C. Heyn, Bauer and Wetzel[1] made quite an extensive investigation into the heat conductivities and specific heats of various ceramic materials in the fired state. They found the mean specific heat of fire brick to be .236 over the interval 20–600°C and .263 over the interval 20–1200°C. In addition to the previous citations, Green,[2] Steger,[3] Magnus,[4] Tadokoro,[5] Wietzel,[6] Knote,[7] and others have determined specific heats for a variety of ceramic materials and bodies by using the method of mixtures.

White[8] carried out a very extensive series of experiments on silicate specific heats. This method consisted of a very refined modification of the method of mixtures, every precaution being taken to eliminate errors. By virtue of Dr. White's extensive experience in calorimetric work, his values for the specific heat of quartz can be looked upon as being the most accurate available in the literature. Table II shows the average values he obtained for the various materials experimented with and Fig. 1 gives a graphical illustration of the average values for quartz.

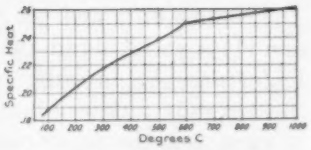

FIG. 1.—Showing the specific heats of quartz according to Walter P. White's data.

The method of mixtures in one modification or another and the method based on Newton's law of cooling have been used in the past almost exclusively for the determination of specific heats. Both of these methods are based upon the fundamental assumption that any thermal effects which take place on heating are reversed on cooling. It has long been known that most of the materials employed in the compounding of ceramic bodies undergo various thermal changes on heating which are not reversed on cooling and, lately, considerable

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[1] "Untersuchungen über die Wärmleitfahigkeit feuer fester Baustoffe," *Mitteilungen aus dem Königlichen Materialprüfungsamt*, **32,** 89–199 (1914).

[2] A. T. Green, "The Specific Heat of Magnesite Brick at High Temperatures," *Trans. Ceram. Soc.* (Eng.), **22,** 393–97 (1922–23).

[3] Steger "The Specific Heat of Refractory Materials," *Silikat Z.*, **2,** 203 (1914).

[4] A. Magnus, "Messungen spezifischer Warmerfester Korper die hohen Temperaturen," *Physik Zeitschr.*, **14,** 5–11 (1913).

[5] Y. Tadokoro "On the Determination of the Thermal Conductivity, Specific Heat, Density and Thermal Expansion of Different Rocks and Refractory Materials," Tohoku Imperial University, *Science Reports*, 1st Series, Mathematics, Physics and Chemistry, **10,** 339–410 (1912).

[6] R. Wietzel, "Die Stabilitatsverhaltnisse der Glas und Kristallphase des Siliziumdioxydes," *Z. f. Anorg. Chem.* **116,** 71–95 (1921).

[7] Knote, "Note on the Specific Heat of Clay," *Trans. Amer. Ceram. Soc.*, **14,** 394–98 (1912).

[8] W. P. White, "Silicate Specific Heats," *Amer. Jour. Sci.*, **47,** 1–43 (1919); "Specific Heats of Silicates and Platinum," *Amer. Jour. Sci.*, **28,** 334 (1909).

effort has been expended in trying to develop a method for specific heat determinations which would account for these irreversible thermal changes. With this in view, Navias[1] used a calorimetric method in which a measured amount of electrical energy was applied to the calorimeter. By measuring the amount of electrical energy needed to heat the empty calorimeter to a given temperature and likewise, measuring the amount of electrical energy needed to heat the calorimeter with the sample in place, it is evident that any difference must be the sum total of heat absorbed or evolved by the sample. Using this method, it was possible for the first time to give correct values for the interval specific heats of ceramic materials which undergo irreversible thermal changes. The values obtained by Navias showed the interval specific heats of raw clays to be about twice as great as had ordinarily been supposed. Unfortunately, in order to avoid heat losses which would have made the errors in a determination excessively large, it was found necessary to carry out the experiments in vacuo. This, of course, precluded the method for the determination of the values most urgently desired because it was not applicable for materials containing combustible matter. However, the method can be easily modified so as to permit a controlled atmosphere around the sample and, if so done, would then be applicable to the cases involving oxidizable materials. Table III shows the interval specific heat values obtained by Navias for the materials in question.

TABLE II

SPECIFIC HEATS OF SILICATES FROM 0–t°C (White)

Temp.	Quartz	Cristobalite	Anorthite	Albite	Microcline	Wollastonite	Diopside	Amphibole	Pseudo Wollastonite
100	.1868	.1883	.1902	.1948	.1871		.1924	.2033	.1844
300	.2168	.2334	.2143	.2204	.2108		.2164	.2298	.2045
500	.2379	.2426	.2297	.2364	.2261		.2314	.2461	.2171
600	.2511								
700	.2543	.2509	.2399	.2474	.2371	.2274	.2421	.2576	.2259
900	.2596	.2569	.2481	.2561	.2451	.2344	.2500	.2661	.2324
1100	.2641	.2625	.2551	.2630	.2511	.2401	.2563	.2731	.2379
1160						.2416			.2394
1300		.2663	.2629						.2426
1400		.2680	.2674						.2448

It will be observed that there is a marked heat absorption up to about 900°C, after which there is in three of the samples, apparently, a very large heat evolution between 900 and 1200°C. This heat evolu-

[1] L. Navias, "Measurement of the Heat Absorbed and Evolved by Clays during Firing and Cooling," *Jour. Amer. Ceram. Soc.*, **6** [12], 1268–98 (1923).

tion is especially marked in the case of the A-1 English china clay and the North Carolina kaolin. These thermal changes are, obviously, not accounted for by the method of mixtures as is evidenced by the fact that the values obtained by Knote,[1] who used this method, are less than half as great as the above values for the same general class of materials.

The next series of experiments undertaken with the object of measuring the interval specific heats of ceramic materials was made by Cohn,[2] who used a differential thermal method entirely different from any hitherto used for specific heat determinations. This method was based upon the behavior of the sample under a definite heat treatment as compared to that of a sample of known specific heat. The reference material used was one of the fired fireclay bodies that had been investigated by Heyn, Bauer and Wetzel.[3] Considerable errors are inherent in this method because of the fact that the final calory-temperature curve is obtained by combining several other curves. It fails more or less to account for the oxidation reactions because of the fact that the sample was placed in a platinum crucible which would, at best, permit only a limited oxidation. In all probability, the greatest error in connection with his procedure lies in his choice of the weight of sample to use. He used about two grams of material in each case. The author has found that, for material undergoing a thermal change, there is a definite weight which will give the greatest thermal effect. That is, Cohn could have varied his sample weight considerably in some cases without changing the value of the temperature-difference time curve. Table IV shows the values obtained by Cohn for the interval specific heats of the various materials he investigated.

TABLE III

HEAT ABSORBED IN CALORIES PER GRAM PER DEGREE ON HEATING AIR-DRIED (110°C) SAMPLES OF CLAY OVER THE TEMPERATURE RANGES GIVEN (Navias)

Temperature range °C	N.C.kaolin	A-1 English china clay	Tenn. ball clay	Raw flint clay
25– 420	0.49	0.42	0.47	0.47
420– 900	0.69	0.95	0.53	0.68
900–1200	0.23	0.075	0.51	0.24
25–1200	0.50	0.55	0.51	0.50

At this point it is undoubtedly pertinent to ask, aside from the investigations of Cohn and Navias, what evidence we have that

[1] *Loc. cit.*

[2] W. M. Cohn, "The Problem of Heat Economy in the Ceramic Industry," *Jour. Amer. Ceram. Soc.*, **7** [5, 6, 7], 359–76, 474–88, 548–62 (1924).

[3] *Loc. cit.*

TABLE IV

MEAN SPECIFIC HEAT IN THE INTERVAL 20 to t°C (Cohn)

Temperature	Zettlitz kaolin	China clay	Artificial corundum	Sillimanite	Feldspar	Rose quartz	Norwegian quartz	Hohenbaca sand	Cristobalite	Chalcedony	Green porcelain	Fired porcelain	Green stoneware	Fired stoneware	Halle clay	Green chamotte	Fired chamotte	Green porcelain glaze	Fired porcelain glaze
100	.201	.200	.203	.161	.161	.190	.190	.190	.194	.167	.185	.189	.181	.186	.189	.191	.197	.170	.179
200	.203	.202	.211	.161	.162	.205	.206	.205	.212	.172	.187	.195	.183	.192	.195	.194	.202	.174	.181
300	.213	.213	.223	.163	.168	.215	.217	.214	.237	.175	.197	.203	.192	.203	.211	.204	.213	.182	.189
400	.226	.226	.231	.167	.179	.226	.226	.223	.238	.177	.213	.212	.201	.212	.223	.211	.220	.193	.197
500	.249	.248	.242	.170	.191	.239	.239	.233	.244	.185	.228	.222	.215	.223	.248	.232	.231	.208	.199
600	.415	.415	.231	.173	.202	.256	.256	.251	.248	.189	.332	.232	.292	.234	.348	.347	.238	.247	.202
700	.430	.438	.239	.174	.211	.257	.257	.254	.252	.193	.324	.245	.289	.275	.344	.331	.244	.238	.204
800	.426	.424	.272	.175	.222	.259	.260	.257	.257	.198	.318	.264	.279	.286	.331	.311	.251	.259	.211
900	.438	.439	.287	.172	.229	.262	.263	.262	.261	.203	.324	.287	.281	.296	.323	.322	.260	.278	.218
1000	.428	.429	.304	.175	.246	.267	.267	.267	.226	.210	.331	.304	.289	.307	.344	.343	.277	.280	.230
1100	.422	.429		.195	.260					.218	.354	.337	.311	.324	.358	.365	.288	.290	.245
1200	.415	.416		.199	.262						.363		.328		.369	.384		.299	
1300	.406	.407		.205							.373		.340			.402		.307	
1400	.410	.412		.202							.383					.415		.292	

clays and other ceramic materials undergo thermal changes and, if they do, what is the extent of these thermal processes? The thermal phenomena occurring in clays on heating were first examined by H. le Chatelier[1] in 1887. This preliminary survey has since been extended and elaborated upon by a number of investigators. They observed accelerations and retardations in the rate of heating of the various clays. Mellor and Holdcroft[2] determined from time-temperature curves, obtained by a differential thermal method, that kaolinite underwent an endothermic reaction just above 500°C, continuing until a maximum was reached at about 650°C. Exothermic reactions took place at about 800, 900, and 1000°C. In the case of china clay, the endothermic reaction amounted to 42 calories per gram. The exothermic reaction at about 800°C, probably due to a polymerization of the alumina, amounted to about 21.5 calories per gram. Qualitative work along this line has been carried out by Rieke,[3] Ashley,[4] Wallach,[5] Satoh[6] and others; all of whom have shown that the various clays undergo enthodermic reactions in the neighborhood of 550°C and exothermic reactions in the neighborhood of 950°C.

Houldsworth and Cobb[7] and Sokoloff[8] in an extensive series of experiments on the effect of heat on clays, have shown that some water was lost at 100°C followed by an ever-increasing amount as the temperature was raised until it reached a maximum between 600 and 800°C after which there is practically no loss.

The Method

1. Theoretical Considerations

The method employed in this investigation is based upon the fundamental assumption that the change in temperature of any body is dependent upon its specific heat, its mass, and the quantity of heat added. This is summarized in the general equation:

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[1] H. le Chatelier, *Bull. Soc. Min.*, **10,** 207 (1887); *Z. Phys. Chem.*, **1,** 396 (1887).

[2] J. W. Mellor and A. D. Holdcroft, "The Chemical Constitution of the Kaolinite Molecule," *Trans. Ceram. Soc.* (Eng.), **10,** 94–120 (1910–11); **11,** 169–73 (1911–12).

[3] R. Rieke, "Einige Beobachtungen über den Gluhverlust von Kaolinen und Tieb," *Sprechsaal*, **44,** 637–40 (1911).

[4] H. E. Ashley, "The Decomposition of Clays, etc.," *Jour. Ind. Eng. Chem.*, **3,** 91–94 (1911).

[5] R. Wallach, *Compt. Rend.*, **157,** 48–50 (1913).

[6] S. Satoh, "A Study of the Heating and Cooling Curves of Japanese Kaolinite," *Jour. Amer. Ceram. Soc.*, **4,** 182–94 (1921).

[7] H. S. Houldsworth and J. W. Cobb, "The Behavior of Fireclays, Bauxites, etc., on Heating," *Trans. Ceram. Soc.* (Eng.), **22,** 111–37 (1922–23).

[8] A. M. Sokoloff, "Zur Frage des Molekularen Zerfalles des Kaolinits im Anfangs-Stadium des Gluhens," *Tonind. Ztg.*, **36,** 1107–10 (1912).

(1) $C = S \times t \times m$, in which
C = number of calories added
S = specific heat of the material
m = mass of the material
t = rise in temperature of the material

If the same number of calories be added to two different masses, m and m_2, of the same substance, the temperature of each mass will be directly proportional to the masses, m, and m_2, since their specific heats would be the same. However, if the same number of calories be added to two different masses, m, and m_2, of different substances, the temperature of each mass will not only be dependent upon the respective mass of each substance but will also depend upon the specific heats of the two substances.

Assume two different masses, m_1, and m_2, which are receiving heat. According to equation (1), one can write

$C_1 = S_1 \times t_1 \times m_1$ and $C_2 = S_2 \times t_2 \times m_2$, in which
C_1 and C_2 = number of calories added to each mass respectively
S_1 and S_2 = specific heats of m_1 and m_2 respectively
t_1 and t_2 = temperature of m_1 and m_2 respectively

If C_1 and C_2 are taken equal, one can write

(2) $$S_1 \times t_1 \times m_1 = S_2 \times t_2 \times m_2$$

If S_1, t_1, m_1, t_2 and m_2 are known, S_2 can be readily calculated.

In the method employed in this investigation, there is the relation as expressed in equation 2. There are two weighed samples, m_1, and m_2, which receive the same number of calories and are so arranged that their temperatures can be measured. The specific heat, S_1, of m_1 is known from previous determinations. In order that the two samples may receive the same number of calories, each is placed in either of two identical platinum containers and suspended in a uniform temperature space of an electric furnace. Since the containers are of uniform size and in a uniformly heated area, it is assumed that the surface of each sample receives the same heat treatment. Each sample has a thermo-element inserted in it whereby its temperature is obtained. The reference sample is quartz of which the specific heat is accurately known from 0–1400°C. Thus, the conditions required by equation 2 are met and it is possible to calculate the specific heat, S_2, of the material under investigation. Through the kindness of Walter P. White, the quartz which was used as a reference material was the identical material used by him in his investigation into the specific heat of quartz and various silicates.

The assumption that, since both samples occupy the same volume in a uniform temperature area, they will each receive the same heat treatment and will, therefore, attain temperatures which are dependent upon their relative masses and specific heats, is more or less arbitrary.

The actual temperature that two samples so situated will attain is dependent upon several factors as follows:

1. The number of calories applied to each sample by radiation from the furnace walls, assumed in this case to be the same for both samples.
2. The mass of each sample.
3. The specific heat of each sample.
4. The reflecting and radiating power of the surface of each sample.
5. The granularity of the samples.
6. The transformations of a thermal nature which take place in the samples.
7. The heat conducted into or away from the samples by the thermocouple leads and the device used to suspend the samples in the furnace.
8. The thermal conductivity of the materials which compose the samples.

If the surfaces of all samples were the same, their reflecting and radiating power would be the same and could be disregarded. In order to meet this condition, either sample was placed in one of two platinum containers of exactly the same shape and size. In order to allow for the free play of air over the samples which is essential in order that the combustible and other oxidizable materials can be oxidized, each container was perforated by numerous small holes.

All samples were ground to the same general degree of fineness, namely, to pass a 100-mesh sieve. Therefore, any error attributable to this source is uniform for all determinations.

The suspension device and thermocouples were similar for both samples and a more or less uniform error is, therefore, introduced from this source. If the thermocouple leads were not insulated, heat would flow from the furnace into the wires and, as the temperature indicated is that of the junctions, the indicated temperature would not represent the temperature of the samples. In order to guard against this, the thermocouple leads were passed through a $\frac{3}{4}$-inch diameter "Sil-O-Cel plus clay" pyrometer protection tube, which also served to suspend the samples in the furnace.

The thermal conductivity of quartz is definitely known and provides the same factor in all experiments. The thermal conductivity of the various bodies and materials investigated is not necessarily the same and therefore introduces an error into all determinations. However, this error can be considered as being small because of the fact that the thermal conductivity of most ceramic materials hovers around a mean value. This is adequately shown by the work of Wologdine,[1] von

[1] S. Wologdine, "Über das Warmeleitungsvermogen der feuerfesten Produkte," *Sprechsaal*, **33**, 454 (1908). "Untersuchungen über die Warmleitfähigkeit, Porosität und Gasdurchlassigkeit der feuerfesten materialen," *Sprechsaal*, **34**, 611–14 (1909).

Rinsum,[1] Brown,[2] Heyn, Bauer and Wetzel,[3] Green,[4] Doughill, Hodsman and Cobb,[5] and others.

Of course the thermal conductivity of the green clays is, in all probability, not the same as the fired material but, since these values are not known, the assumption is made that they are not radically different.

FIG. 2

A = neutral
B = sample
C and *E* = leads to millivolt meter
D = constant cold junction.

The scheme whereby the behavior of a sample undergoing heat treatment was ascertained by comparison with a neutral body was devised and first employed by Sir Roberts-Austen[6] who used it to determine the thermal behavior of the ferrous metals, using nickel as a reference body. Figure 2 shows a diagrammatic sketch of the thermocouple arrangement employed in this type of investigation.

Instead of using two distinct thermocouples for the determination of the temperature and temperature-difference of the samples as illustrated in Fig. 2, it was found preferable to use one thermocouple which had four junctions. This arrangement is shown diagramatically in Fig. 3.

Since the e.m.f. of a couple is dependent upon the difference in temperature of the two junctions, it is essential that one junction be constant in order to obtain comparable voltages. The cold junction was kept at 0°C by having it immersed in melting ice contained in a Dewar vacuum bottle. The thermocouples were calibrated by means of the method of fixed melting points, using metals of certified freezing point obtained from the U. S. Bureau of Standards. From the data thus obtained, a curve, Fig. 8, was drawn by plotting temperatures against millivolts.

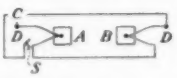

FIG. 3

A and *B* = samples (quartz and test)
D = constant cold junction
C = leads to millivolt meter.
S = switch

[1] W. Von Rinsum, "Die Warmleitfahigkeit von feuerfesten Steinen bei hohen Temperaturen, u.s.w.," *Chem. Zentral.*, **2**, 94 (1919).

[2] G. Brown, "The Relative Thermal Conductivity of Silica and Clay Refractories," *Trans. Amer. Ceram. Soc.*, **16**, 382–85 (1914).

[3] *Loc. cit.*

[4] A. T. Green, "The Thermal Conductivity of Refractory Materials at High Temperatures," *Trans. Ceram. Soc.* (Eng.), **21**, 394–414 (1921–22).

[5] G. Doughill, H. J. Hodsman and J. W. Cobb, "The Thermal Conductivity of Refractory Materials," *Jour. Soc. Chem. Ind.*, **34**, 465–71 (1915).

[6] Sir Roberts-Austen, "Fifth Report to the Alloys Research Committee: Steel." *Proc. Inst. Mech. Engrs.* (British), 35–102 (1899).

Anyone familiar with curves will recognize that a curve of this type can be represented by the following equation:

(3) $E=at-bt^2$, in which t = temperature in degrees Centigrade
E = microvolts a and b = constants.

By determining E at two different temperatures, a set of simultaneous equations are obtained by means of which the constants, a and b, can be calculated. It was found that $E=9{,}700$ when $t=231.9$ and $E=27{,}400$ when $t=658.9$. Substituting these values in equation (3), we get

$$(1)\ 231.9a-(231.9)^2b=\ 9{,}700$$
$$(2)\ 658.9a-(658.9)^2b=27{,}400 \text{ or}$$

$$(1)\ 231.9a-\ 53{,}777.6b=\ 9{,}700 \qquad \text{multiplying (1) by}$$
$$(2)\ 658.9a-434{,}149.2b=27{,}400 \qquad \text{2.84, we get}$$

$$(1)\ 658.9a-152{,}782.2b=27{,}557.7 \qquad \text{substracting to}$$
$$(2)\ 658.9a-434{,}149.2b=27{,}400 \qquad \text{eliminate (1) we get}$$

$$658.9a-152{,}782.2b=27{,}557.7$$
$$658.9a-434{,}149.2b=27{,}400.0$$

$$b=.00056 \qquad \text{Substituting } b \text{ in equation (1) we get}$$

$$231.9a-(53{,}777.6).00056=\ 9{,}700$$
$$a=41.9577$$

Thus the equation for the standardization curve of the thermocouple is

(4) $$E=41.9577t-.00056t^2$$

This is a quadratic equation. t can be calculated for any desired E. For example, the temperature, t, is calculated which corresponds to an E of 9,700. Rewriting equation (3), we get the following quadratic equation,

$$-bt^2+at-E=0$$

The formula for solving this equation is

$$t=\frac{-a\pm\sqrt{a^2-4bE}}{2b}$$

Substituting the values of the constants, a and b, and E in the above equation, we get

$$-t=\frac{-41.9577\pm(41.9577)^2-(4\times.00056\times-9{,}700)}{2(-.00056)}$$

$$t=\frac{-41.9577\pm(1760.3899-21.728)}{-.00112} \text{ or}$$

$$t = \frac{-41.9577 \pm 41.6973}{-.00112}$$

and assuming plus to be correct, we get

$$t = \frac{-0.2594}{-0.00112} = 231.91$$ degrees centigrade as the calculated temperature when E is 9,700.

It should be evident that t can be calculated with considerably greater precision than it can be read from a standardization curve.

Recalling that the differential thermocouple has the one junction inserted in the reference material quartz, and the other in the test sample, it is evident that this couple will not have a constant cold junction because the temperature of the furnace will be continually rising during an experimental run. Furthermore, if the test sample undergoes a very marked endothermic reaction, it may be as much as 100°C colder than the quartz at some particular temperature. However, this temperature will vary as the reaction becomes more or less intense. On the other hand, if the test sample undergoes an exothermic reaction, it may become much hotter than the quartz and, as before, this temperature will vary with the intensity of the reaction. In the first case, the junction inserted in the test piece would be the cold junction, usually a constantly varying cold junction, and as the test sample becomes the hotter, as in the second case, the junction inserted in the quartz becomes the cold junction. In other words, by employing a differential thermocouple, one is confronted with the situation of a constantly varying cold junction temperature. In addition to this, the temperature difference is continually varying. It is to be recalled that the e.m.f. generated by a thermoelement is not only dependent upon the difference in temperature but, also, upon the actual temperature of the two junctions. Evidently, if a differential millivoltage of 2.5 is obtained, its temperature equivalency could neither be calculated by equation (4) nor be determined by referring to the standardization curve of the thermocouple. It is impossible to do this because both the curve and the equation are based on the consideration that one of the junctions is constant, namely, maintained at 0°C. The question, then, is "can the exact temperature corresponding to any given e.m.f. generated by a differential thermocouple be determined." It can be accurately determined if the differential coefficient of E with respect to t is known. Referring to equation 3, $E = at - bt^2$; differentiating E with respect to t gives

(5) $$\frac{dE}{dt} = a - 2bt,$$ in which

dE = the measured differential voltage.

dt = the differential temperature corresponding to dE
a = 41.9577
t = the temperature of one of the junctions
b = .00056

The temperature of one of the junctions is determined by the thermoelement inserted in the quartz which has a constant cold junction temperature of 0°C. Equation 5 can be written in the following form:

$$dt = \frac{dE}{a - 2bt}. \tag{6}$$

Equation 6 is the working equation whereby the temperature differences are calculated. For example, the temperature is calculated which corresponds to a differential microvoltage of 200 when one of the junctions is at 203.2°C. Substituting the equivalents of the characters in equation 6, we get

$$dt = \frac{200}{41.9577 - 2(-.00056 \times 203.2)} = 4.7°\text{C}$$

as the differential temperature which corresponds to a microvoltage of 200 at a cold junction temperature of 203.2 C. The temperature of the hot junction is, of course, 207.9° C.

Obviously, a differential microvoltage of 200 can correspond to as great a number of temperatures as there are values for t, which may be any number from zero to the extreme limit of the thermocouple. Unfortunately, many investigators who have used the differential thermocouple have taken the differential voltages to represent the same temperatures as the corresponding voltages when generated by a couple with a constant cold junction and have, therefore, introduced gratuitous errors into their work.

It was found expedient to take the temperature of the quartz at intervals of about 2.5 millivolts. As these readings were always taken at the same millivoltages, the corresponding values for t were calculated. Similarly, since t was constant in all cases, $a - 2bt$ would be the same for each experiment and was, therefore, calculated. This is in order to avoid their recalculation in all subsequent determinations. The values for t, $a - 2bt$, and the specific heat of quartz at the various temperatures are assembled in Table V.

The rate of heating was the same in all cases. Any errors attributable to these factors are constant.

The quantity of material which is used for each test piece is quite important and should be just sufficient to give the maximum thermal effect. This is evident from a consideration of the conditions incident upon an experimental determination. If the quantity of material be very small, it is easily conceivable that any thermal effect it may

undergo would be lost owing to the extremely small amount of heat involved. The heat evolved or absorbed would be dissipated in the thermocouple wires or, from one cause or another, produce an effect totally imperceptible by the method employed to measure it. Evidently then, there must be sufficient material used so that any thermal effects will be of such magnitude as to be comparable to the sensitiveness of the method employed to measure them. On the other hand, it is not permissible to use more than the amount required to show the maximum thermal effect because these processes, whether chemical or physical, take place at a definite temperature regardless of whether there is one gram or one pound undergoing the change. This is necessary because the weight is used in the specific heat calculation.

2. General Method (Synopsis) The materials to be tested were finely ground and a weighed sample placed in a small perforated platinum crucible. A similar crucible was filled with a weighed quantity of quartz. The two crucibles of material were placed in a uniform temperature zone of an electric furnace and the temperature raised to about 1050°C in about one hour. At arbitrarily chosen intervals, the temperature of each sample was measured by a chromel-alumel thermocouple imbedded in the material.

TABLE V

Millivolts	Temperature °C	Specific heat of quartz	$a - 2bt$
2.5	59.7	0.1823	41.874
4.5	107.1	0.1881	41.837
6.5	155.8	0.1963	41.783
8.5	203.6	0.2036	41.729
10.5	251.0	0.2104	41.676
12.5	299.4	0.2166	41.621
14.5	347.7	0.2223	41.577
16.5	396.5	0.2278	41.512
18.5	445.0	0.2326	41.459
20.5	494.0	0.2374	41.404
22.5	540.2	0.2425	41.352
24.5	590.3	0.2465	41.296
26.5	639.0	0.2499	41.241
28.5	687.0	0.2534	41.187
30.5	736.0	0.2553	41.133
32.5	785.3	0.2566	41.077
34.5	834.2	0.2579	41.022
36.5	883.0	0.2591	40.968
38.5	931.5	0.2604	40.914
39.5	956.1	0.2609	40.886
40.5	980.6	0.2615	40.858
41.5	1004.8	0.2620	40.832
42.5	1029.0	0.2626	40.806
44.5	1076.5	0.2636	40.751

3. Furnace The electric furnace consists of an alundum core 3 inches in internal diameter and 18 inches long wound with about 43 feet of 15 gage nichrome IV resistance wire. The core, made with especially thin ($\frac{1}{4}$ inch) and porous walls, has a pitch of 3 turns to the inch. Each end of the core is fitted into a Sil-O-Cel (90% Sil-O-Cel plus 10% ball clay) disk and made snug by forcing alundum cement into any cracks that existed. The disks are about 2 inches thick and of such diameter that they just fit into a double-walled iron cylinder 18 inches long. The inner wall of the iron cylinder is perforated with numerous small holes and the outer wall has four threaded

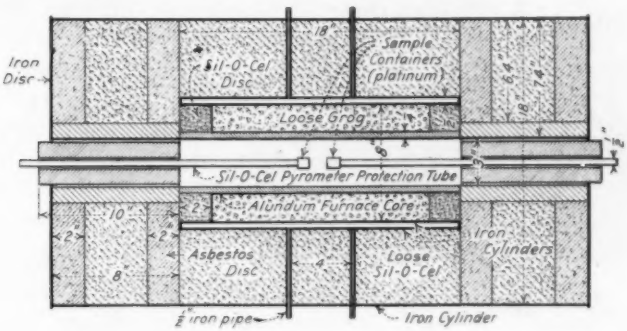

FIG. 4. Diagramatic cross-section through furnace, nichrome wire wound.

openings into which are screwed $\frac{1}{2}$-inch iron pipes. The space between the alundum core and the iron cylinder is filled with coarse grog. The ends of the Sil-O-Cel disks are coated with a paste of sodium silicate and asbestos which forms an air tight joint between the furnace core and the iron cylinder. This compact unit is suspended in an iron cylinder 43 inches long and 18 inches in diameter by means of the four iron pipes which project through holes placed in the walls of the horizontal line of the cylinder. Thus when air is allowed to flow through the iron pipes, it passes into the space between the walls of the double-walled cylinder (the walls being sealed together at each end), through the holes of the inner wall into the loosely packed grog, and diffuses through the walls of the alundum core into the area in which is located the samples. This arrangement was adopted as being the most expedient method of introducing air into the furnace uniformly. However, it was found unnecessary to introduce excess air into the furnace in the cases investigated. Butted up against either end of the alundum core is a Sil-O-Cel cylinder 3 inches in internal diameter and 8 inches long. Either cylinder is suspended in the central line of the furnace by two asbestos disks 18 inches in diameter and 2 inches in thickness. A Sil-O-Cel end plug of about $2\frac{7}{8}$ inches external diameter and 12 inches long

fits snugly into either of the Sil-O-Cel cylinders and against the furnace core. Each of the Sil-O-Cel plugs is pierced horizontally by a $\frac{7}{8}$-inch hole through which is inserted a Sil-O-Cel thermocouple protection tube 18 inches long and $\frac{3}{4}$ inch in diameter and so designed as to be capable of carrying two 22-gage thermocouple wires. The ends of the large iron cylinder are closed by means of a detachable iron cover plate. The space in the furnace not occupied by the above named materials is filled with loose Sil-O-Cel powder. The furnace, having a resistance of about 10 ohms, is heated by a 200-v. a.c. circuit. Figure 4 shows a diagrammatic sketch of a cross-section through the furnace.

4. Rheostat A 300-ohm rheostat capable of carrying 30 amperes was used. The dial was equipped with a movable contact which could be so manipulated as to form 75 different contacts, giving ample flexibility in the speed of heating. The rheostat was so regulated as to obtain the same rate of heating in all experiments.

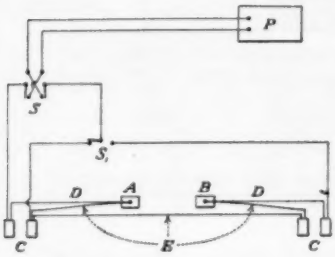

FIG. 5.

P = Potentiometer
C = Cold junctions (0°C)
E = Chromel thermocouple wire
D = Alumel thermocouple wire
A = Quartz
B = Sample
S_2 and S = switch

5. Sample Container The sample containers consist of perforated platinum crucibles (150 perforations to the square inch) 2 cm. long and 1 cm. in diameter.

6. Temperature Measuring Equipment The temperature of the test pieces as well as that of the reference material was ascertained by measuring the voltage developed by a No. 22 gage chromel-alumel thermocouple inserted in the materials under test. The high voltage adds considerably to the precision with which the temperature can be measured and this type of thermocouple is, therefore, preferable to a noble metal thermocouple for use in this investigation. The voltages developed by the thermocouples were determined by the potentiometer method, using the Brown precision potentiometer.

In the course of an experimental determination, it often happened that first the one and then the other of the two junctions of the differential thermocouple was hotter. This means that the current would flow first in the one direction and then in the other. Since the current must always flow into the potentiometer in the same direction, a double throw reversing switch is installed in the differential thermocouple circuit. Figure 5 shows the wiring system employed in the thermocouple circuits.

7. Rate of Heating Joly,[1] Dana,[2] Mellor,[3] Dittler,[4] and others have emphasized the importance of the time of heat treatment when one is investigating the thermal properties of silicates. In order to keep any error arising from the speed at which heat was applied to the test pieces constant, the rheostat was so manipulated as to permit the attainment of a temperature of 1050°C in about 55 minutes—a time sufficient for the necessary manipulations involved in making a determination. All samples were dried overnight at 65°C.

8. Advantages of Method (*a*) This method gives values for the interval specific heats which indicate the actual number of calories required to be added from some outside source (from the fuel) in order to raise the temperature of a given material from 0 to t°C taking into account any and all thermal processes which the material might undergo on being heated.

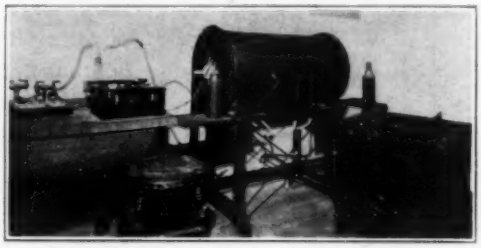

FIG. 6.

(*b*) It gives the exact temperatures at which the various thermal processes begin and end.

(*c*) It gives the actual quantitative figures for the various thermal processes.

(*d*) The apparatus is inexpensive and easy of manipulation.

The values obtained in this investigation and herewith presented are probably correct to within 10% of the absolute values.

Figure 6 shows a photograph of the apparatus used in this investigation.

Experimental Work

1. Standardization of Thermocouples The thermocouples were made of No. 22 gage chromel and alumel wire. They were standardized by noting the voltage generated by the couple when the one junction was at the temperature of melting ice and the other at the freezing temperature of metals of certified freezing points obtained from the U. S. Bureau of Standards. About

[1] J. Joly, Brit. Assn. Report, 750 (1900).

[2] L. I. Dana, "Melting Point of Refractory Materials," *Amer. Inst. Min. Met. Eng.* (Pyrometry), 267–84 (1920).

[3] J. W. Mellor, Clay and Pottery Industries, 32, 247; 37, 309 (1914).

[4] E. Dittler, "Beitrage zur Thermochemie der Silikate," *Z.f. Anorg. Chem.*, 69, 273–304 (1911).

50 cc. of each of the metals, tin, aluminum, zinc and copper, were used. The metal samples were placed in graphite crucibles of approximately 1 inch in internal diameter and 4 inches high. The samples were heated well beyond their melting temperatures in an Ajax-Northrup high frequency induction furnace, after which one junction of the couple being tested was inserted into the metal and voltage readings as a function of time taken. The thermocouple was protected from the metal bath by a thin-walled graphite tube. In order to avoid any possibility of oxidation of the metals, they were covered with pure graphite powder. The voltage decreases in a regular manner until the freezing temperature of the metal is reached after which the voltage remains constant (and likewise the temperature of the metal) until the end of the solidification process, when it again falls regularly. Figure 7 shows a typical curve obtained by plotting voltages against time. The break in the curve gives the voltage generated by the thermocouple at the freezing temperature of the metal in question. The voltages generated at the freezing temperatures of the various metals is as follows:

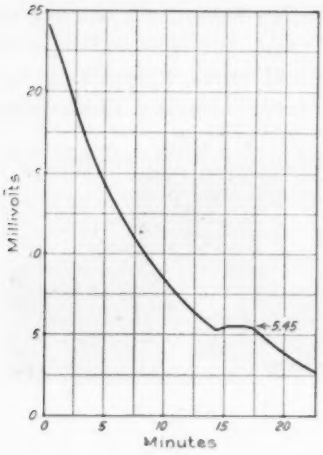

FIG. 7.

Metal	Millivolts	Temperature °C
Tin	9.7	231.9
Zinc	17.4	419.4
Aluminum	27.4	658.9
Copper	44.4	1083.0

Figure 8 shows the average standardization curve.

It is to be noted that this standardization of the thermocouples also served to standardize the Brown potentiometer, as it was used to record the millivolts generated.

2. Rose Quartz Of the materials which Cohn[1] worked with, that which could be obtained with greatest probability of an actual duplication was rose quartz. With the intention of comparing the values obtained by Cohn with those obtained by the method employed

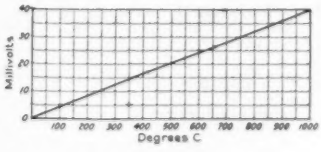

FIG. 8.

[1] *Loc. cit.*

TABLE VI

CHEMICAL ANALYSIS OF THE MATERIALS INVESTIGATED

Total	North Carolina kaolin	Brandywine feldspar	Georgia kaolin	Delaware kaolin	Kentucky ball clay	Magnesia spinel	Florida kaolin	Disapore clay	Oil shale	Firebrick body No.1	Firebrick body No.2	Firebrick body No.3	Firebrick body No.4	Firebrick body No.5
H_2O	16.83	.40	13.83	13.05	8.35		14.86	13–14	.31					
SiO_2	44.50	68.98	45.70	48.15	61.25	2.27	45.67	7–10	45.27	70.58	50.70	56.28	59.46	64.60
Al_2O_3	37.55	17.50	38.20	36.38	25.05	69.53	38.45	72–78	10.44	24.10	41.79	39.50	36.07	30.13
Fe_2O_3	.54	.17	.60	.90	1.30		.75	1.50	3.52	1.49	2.57	2.80	2.72	2.73
TiO_2	.03			.22	1.35		.10			3.05	2.68			1.52
MgO	trace	.10		trace	.20	28.20	.05	trace	7.38	.24	.53	.32	.48	.45
CaO	trace	.20		trace	.10		trace	.20	21.91	.09	.37	.42	.68	.44
K_2O	.75	10.00	.14	.81			.06							
Na_2O		3.05	.20											
MnO		.004			1.90									
R_2O_3 (principally Al_2O_3)										.55	1.10	1.10	.41	.63
Ash									.60					
Volatile matter and fixed carbon									38.72					

TABLE VII

SPECIFIC HEATS OVER THE INTERVAL 0–t°C

Rose Quartz		North Carolina kaolin		A-1 English china clay		Brandywine feldspar		Georgia kaolin		Delaware kaolin	
Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat
156.0°C	.194	107.1°C	.381	104.5°C	.369	108.5°C	.209	102.8°C	.380	105.7°C	.370
205.0	.201	155.8	.394	152.0	.382	157.7	.218	151.5	.391	153.4	.386
252.9	.208	203.6	.402	200.0	.393	206.0	.225	198.8	.402	203.6	.393
301.3	.214	251.0	.415	248.6	.406	253.4	.234	247.7	.414	253.4	.405
350.6	.221	299.4	.426	297.5	.417	301.8	.242	296.5	.424	302.7	.416
398.4	.227	347.7	.438	345.3	.427	350.1	.248	344.4	.435	350.1	.430
446.4	.233	396.5	.451	392.9	.438	398.4	.255	391.7	.448	396.5	.444
495.4	.236	445.0	.462	440.2	.449	446.5	.261	437.8	.458	442.6	.455
541.7	.242	494.0	.477	480.9	.465	496.0	.267	480.9	.472	484.8	.470
592.3	.246	540.2	.502	512.6	.487	542.2	.272	510.2	.498	515.5	.494
641.0	.249	590.3	.532	537.0	.517	591.2	.277	534.2	.529	537.6	.528
689.9	.251	639.0	.568	552.8	.553	639.0	.282	557.6	.557	567.8	.549
739.4	.254	687.0	.547	616.2	.538	687.5	.284	628.7	.536	628.3	.539
789.7	.256	736.0	.517	705.8	.508	737.6	.286	722.4	.505	713.1	.513
839.5	.257	785.3	.505	780.5	.493	787.8	.288	781.8	.500	778.5	.505
888.8	.257	834.2	.505	831.8	.493	838.6	.289	834.2	.500	831.7	.504
939.3	.258	883.0	.505	884.9	.493	889.3	.289	884.7	.501	883.0	.503
989.4	.260	931.5	.505	934.0	.493	940.8	.290	935.4	.501	933.4	.504
1039.7	.261	956.1	.509	961.0	.492	991.4	.292	962.2	.502	960.0	.504
		980.6	.483	1048.0	.465	1040.8	.293	1022.2	.488	1036.8	.483
		1004.8	.507	1013.2	.495			1013.1	.504	1013.6	.504
		1029.0	.512	1035.8	.499			1035.9	.507	1034.9	.510

TABLE VII(*continued*)

SPECIFIC HEATS OVER THE INTERVAL 0–*t*°C

Kentucky ball clay		Magnesia spinel		Florida kaolin		Disapore clay		Oil shale		Firebrick body No. 1	
Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat
109.0°C	.333	149.6°C	.201	109.5°C	.359	157.2°C	.333	107.1°C	.339	105.9°C	.324
158.2	.348	196.4	.207	159.1	.375	206.5	.343	163.0	.337	155.8	.334
206.9	.358	243.3	.214	207.9	.388	255.3	.355	251.4	.295	206.0	.341
255.9	.372	291.3	.220	257.2	.401	306.1	.364	495.8	.208	255.3	.352
307.6	.380	339.5	.225	307.1	.413	356.4	.372	544.4	.212	304.7	.367
360.2	.387	398.9	.229	356.9	.423	403.2	.385	617.2	.238	353.5	.373
405.1	.401	437.3	.234	402.8	.440	448.8	396	675.7.	.240	403.7	.382
449.8	.415	487.2	.237	448.4	.450	487.2	.413	1050.0	.285	453.8	.389
489.2	.431	534.4	.242	489.6	.467	498.0	.445			494.0	.403
516.0	.457	584.0	.246	515.1	.498	516.3	.485			521.3	.429
545.7	.481	632.2	.250	540.0	.528	577.4	.476			543.3	.458
605.1	.476	681.4	.252	561.6	.558	675.4	.443			608.4	.449
676.3	.463	731.6	.254	657.9	.517	738.9	.437			689.4	.429
736.0	.459	783.4	.255	736.0	.499	791.1	.438			744.4	.430
789.7	.461	834.2	.255	792.6	.498	841.5	.439			795.1	.431
840.5	.461	886.4	.255	844.0	.499	891.8	.440			845.5	.433
890.8	.462	939.3	.256	895.2	.499	941.7	.441			897.7	.433
941.3	.462	991.3	.257	945.6	.501	967.1	.442			946.7	.435
968.3	.463	1042.2	.257	971.7	.501	993.3	.446			990.3	.428
996.7	.466			1011.5	.497	1018.5	.444			997.3	.438
1018.5	.466			1019.5	.504	1043.7	.445			1044.7	.441
1042.7	.462			1044.9	.507						

TABLE VII (*concluded*)

SPECIFIC HEATS OVER THE INTERVAL 0–t°C

Firebrick body No. 2		Firebrick body No. 3		Firebrick body No. 4		Firebrick body No. 5	
Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat	Temp.	Specific heat
101.4°C	.331	102.3°C	.327	102.9°C	.324	99.5°C	.321
152.9	.333	155.8	.325	154.4	.329	154.6	.316
203.6	.338	206.0	.331	204.5	.332	206.0	.319
255.3	.344	256.8	.340	254.6	.343	256.8	.328
306.6	.352	306.6	.350	306.6	.350	309.0	.337
358.8	.360	356.3	.359	358.3	.357	359.0	.343
409.0	.368	405.2	.369	406.3	.368	411.7	.351
459.0	.376	452.2	.379	454.1	.378	465.8	.354
498.8	.390	496.9	.390	496.9	.391	496.9	.378
527.2	.414	525.7	.413	524.7	.414	524.2	.399
550.6	.442	546.7	.439	553.5	.435	550.6	.423
614.3	.434	604.5	.438	613.3	.432	610.6	.419
687.0	.423	674.9	.427	678.7	.424	688.4	.403
740.4	.423	741.3	.420	741.8	.418	742.3	.403
791.6	.425	794.1	.420	794.1	.420	796.5	.403
843.0	.425	845.9	.421	845.4	.421	847.4	.404
895.7	.425	896.2	.421	898.1	.421	898.1	.405
949.1	.425	951.0	.421	950.1	.421	966.7	.399
983.0	.422	986.5	.417	988.9	.415	977.1	.405
995.9	.431	999.2	.427	998.2	.426	1001.1	.411
1044.7	.431	1046.7	.428	1036.2	.426	1046.2	.413

in this investigation, the values for the interval specific heat of rose quartz were determined. The sample was obtained from near Custer, South Dakota, being kindly furnished by A. Brant of the Department of Mineralogy. Although the chemical analysis of this particular specimen was not available, E. F. Holden[1] gives the analysis of a typical rose quartz sample obtained from the Custer district to be as follows:

Loss on ignition	.17%	MnO	.0003%
Total solid impurities	.13	Li_2O	.003
Total impurities	.3	Fe_2O_3	.012

As heat is applied, the temperature of the sample rises quite uniformly, following the temperature of the quartz reference sample very closely. Therefore, this material undergoes no marked thermal changes. The calory-temperature curve indicates that slight exothermic processes take place at about 450°C and 850°C. Also, there appears to be a slight endothermic process beginning at about 550°C and extending over a range of about 200°.

Table VII shows the values obtained for the interval specific heat of rose quartz from 0 to t°C.

In Figure 10 is shown the number of calories required to heat one gram of rose quartz from 0 to t°C. Calories are calculated according to equation (1).

3. North Carolina Kaolin

The North Carolina kaolin was mined near Spruce Pine, Mitchell Co., N. C., and has the chemical analysis shown in Table VI.

It was found that 1.15 grams gave the maximum temperature effect and this was, therefore, the quantity used in the final determination. This was ascertained by keeping the weight of quartz constant and using various weights of the clay. Beginning with one gram, the temperature difference continually increased with increasing quantities of clay until 1.15 gram was employed, after which a further increase of clay gave no corresponding increase in temperature differences. In a similar manner it was found that 2.25 grams of quartz gave the maximum temperature effect and this quantity was, therefore, used in this and all other determinations.

An endothermic process begins at about 200°C and extends to about 675°C, reaching its maximum intensity at about 550°C. This endothermic process is due to the driving off of the water contained in the clay. Quantitatively, this reaction absorbs 150 calories per gram of air dried (65°C) clay. This value is obtained from the temperature-calory curve by projecting the curves in a straight line and measuring

[1] E. F. Holden, "The Cause of Color in Rose Quartz," *Amer. Mim.*, **75** [9, 4] (1924).

the calories directly along the central portion. The method of doing this is indicated by the dotted lines on Fig. 9. Such endothermic processes scarcely, if ever, present an exactly horizontal section of the curve and must, therefore, be extrapolated from the curve sections above and below the reaction in question.

An exothermic process appears at about 970°C, the chemical significance of which is not definitely known. The extent of this reaction is 40 calories per gram of air dried (65°C) clay. On the calory-temperature curve, the temperature rises fairly regularly with the inducted heat up to the temperature at which the exothermic process begins. Then appears a sudden rise in temperature of about 70°C, making the clay hotter than the furnace. The loss of heat from the sample then becomes quite large and the temperature falls until it reaches that of the furnace, when it again rises in a regular manner with the inducted heat. In this manner originates the sharp break in the calory-temperature curve. The intensity of the exothermic reaction is obtained by extrapolation of the middle portion of the upper curve section, from the point at which the sample begins to lose an appreciable amount of heat to the furnace, to the middle portion of the lower curve section. If there had been no loss of heat from the sample, the steady rise would have begun at 1041°C so the curve is projected from this temperature. This is illustrated by the dotted lines in Fig. 9.

For all temperatures above those at which exothermic processes occur, it is necessary to extrapolate the upper curve sections from the points at which the samples begin to lose an appreciable amount of heat to the furnace. This is illustrated by the dotted line in Figure 9. Thus, 543 (not 572 calories as read from the original calory-temperature curve) are required to heat one gram of air dried North Carolina kaolin from 0°C to 1100°C. Of course, some heat is lost to the furnace just as soon as the sample gets hotter than the furnace, as is evidenced by the slight upward trend of the curve after starting the exothermic process. However, this loss of heat is greatly overbalanced by the effect of the exothermic process until this process ceases—then appears the sharp break in the curve.

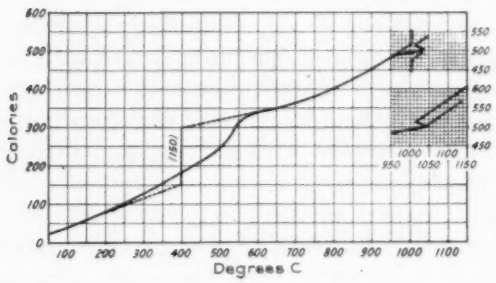

FIG. 9.—The exothermic reaction amounts to 40 calories per gram as read from the calory base line. The endothermic reaction is 150 calories per gram as read from the calory base line.

TABLE VIII

SHOWING THE NUMBER OF CALORIES REQUIRED TO HEAT ONE GRAM OF THE RESPECTIVE MATERIALS FROM 0–t°C

Temp.	A-1 English china clay	Georgia kaolin	Dela-ware kaolin	North Carolina kaolin	Florida kaolin	Ken-tucky ball clay	Dia-spore clay	Oil shale	Mag-nesia spinel	Rose quartz	Feld-spar	Fire-brick body No.1	Fire-brick body No.2	Fire-brick body No.3	Fire-brick body No.4	Fire-brick body No.5
100°C	43	38	36	40	38	37	37	32	20	20	21	38	32	32	37	39
200	87	79	79	80	76	68	70	65	47	37	43	68	68	68	66	67
300	136	130	130	130	125	112	106	75	75	62	70	107	105	104	103	101
400	185	183	180	183	171	159	150	85	101	86	103	150	136	145	144	135
500	240	243	240	245	239	236	232	105	129	113	135	203	195	194	195	188
600	334	332	239	340	326	285	274	135	155	144	168	273	261	268	263	254
700	360	360	379	364	352	320	306	175	181	172	200	305	293	293	293	285
800	405	402	406	403	395	366	350	235	208	202	231	346	340	337	336	325
900	454	451	455	453	450	416	400	270	235	223	262	390	382	379	379	365
1000	487	496	495	496	500	465	450	320	262	157	295	426	419	415	415	401
1100	525	554	545	543	565	507	500	365	290	295	334	475	473	461	462	450
1200												525	526	507	506	497
1300												573	580	555	553	550

4. A-1 English China Clay

This material was kindly furnished by Hammill and Gillispie, Inc., and acknowledgment is here gratefully made.

An endothermic process begins at about 250°C and extends to a bout 725°C, reaching its maximum intensity at about 550°C. This reaction absorbs 123 calories per gram of air dried (65°C) clay.

At a temperature of about 970°C, the calory-temperature curve shows the same sharp break as indicated for North Carolina kaolin, being due to the exothermic reaction taking place. This exothermic process evolves 35 calories per gram of air dried (65°C) clay.

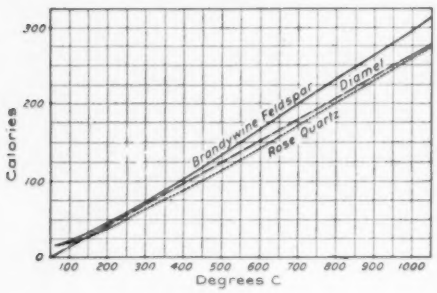

FIG. 10.

The consumption of heat up to any given temperature, the value of vital concern to the industry can be obtained by referring to Fig. 11, in which calories are plotted against temperature. The values for the interval specific heats of A-1 English china clay from 0 to t°C are shown in Table VII.

5. Feldspar

The feldspar used in this investigation is that known as "Brandywine" feldspar. It was mined near Brandywine Summit, Pa., and has the chemical composition shown in Table VI.

The temperature of the feldspar rose uniformly throughout the heating process, showing that feldspar undergoes very little, if any, thermal processes. The values obtained for the interval specific heat of Brandywine feldspar from 0 to t°C are shown in Table VII.

6. Georgia Kaolin

This material was mined near Dry Branch, Ga., and has the chemical composition shown in Table VI.

An endothermic process begins at about 250°C and extends to about 650°C, reaching its maximum intensity at about 550°C. This reaction absorbs 127.5 calories per gram of air dried (65°C) clay.

At a temperature of about 980°C appears the same exothermic reaction as was observed in the case of North Carolina kaolin and A-1 English china clay. This reaction evolves 22.5 calories per gram of air dried (65°C) clay.

As a general statement, one can say that the behavior of primary and secondary kaolin on firing is practically the same. That is, both show a marked endothermic reaction in the neighborhood of 600°C, being due to the expulsion of chemically bound water, and a sharp exothermic reaction at about 975°C, the chemical significance of which is not

definitely known. Either requires an average of about .5 calories per gram per degree in order to raise its temperature from 0 to t°C.

Table VII shows the interval specific heats of Georgia kaolin from 0° to t°C.

7. Delaware Kaolin This material was mined near Hockessen, Del., fires to a light salmon color, and has the chemical composition shown in Table VI.

As in the case of the other kaolins, an endothermic reaction at about 600°C and an exothermic reaction at about 970°C are evident. The endothermal process begins at about 250°C and extends to about 650°C, reaching its maximum intensity at about 550°C. This reaction absorbs 118 calories per gram of air dried (65°C) clay. The exothermic reaction begins at about 975°C and evolves 32 calories per gram of air dried (65°C) clay.

Table VII shows the values for the interval specific heats of Delaware kaolin over the range 0 to t°C.

8. Kentucky Ball Clay This material was mined near Mayfield, Ky., and has the chemical composition shown in Table VI.

Qualitatively, this material shows the same general behavior on heating as the kaolins. However, the intensity of both the endothermic and exothermic reactions is decidedly less pronounced. In fact, the exothermic reaction in the neighborhood of 980°C was so insignificant that it caused no sharp break in the calory-temperature curve, Fig. 12. The endothermal process began at about 250°C and extended to about 680°C, reaching its maximum at about 540°C. This reaction absorbs 90 calories per gram of the air dried (65°C) material.

The exothermic reaction which begins at about 980°C evolves 5 calories per gram of the air dried (65°C) clay.

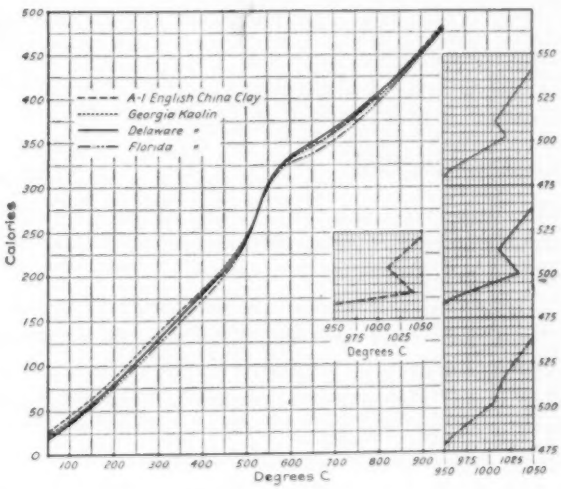

FIG. 11.

The values for the interval specific heat from 0° to t°C are shown in Table VII.

9. Magnesia Spinel As a representative of the spinel groups, the values for the interval specific heats of an artificial spinel (diamel) were determined. An analyzed sample of this material was kindly placed at the author's disposal by H. Fisk, Research Fellow of the U. S. Bureau of Mines. This particular sample has the chemical composition shown in Table VI.

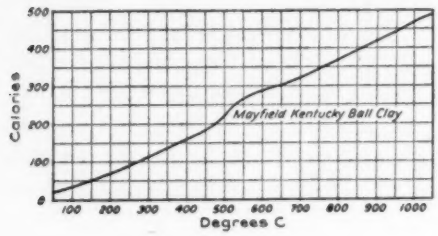

FIG. 12.

The temperature calory curve, Figure 10, is a perfectly straight line, showing that this material undergoes no thermal changes on being heated to about 1050°C.

The values for the interval specific heats of magnesia spinel over the interval 0 to t°C are shown in Table VII.

10. Florida Kaolin This material was mined near Edgar, Putnam Co., Florida, and has the chemical composition shown in Table VI.

As in the case of the other kaolins, an endothermic reaction at about 970°C is very much in evidence. The endothermal process begins at about 250°C and extends to about 675°C, reaching its maximum at about 550°C. This reaction absorbs 122.5 calories per gram of air dried (65°C) clay.

The exothermic reaction begins at 980°C and evolves 10 calories per gram of air dried clay.

The values for the interval specific heats of Florida kaolin over the interval 0 to t°C are shown in Table VII.

11. Diaspore Clay As a typical representative of the diaspore type of clay, a Missouri diaspore clay was selected. This material was kindly placed at the author's disposal by the General Refractories Co., Philadelphia, Pa. It has the chemical composition shown in Table VI.

As in the case of the kaolins, an endothermic reaction took place at about 550°C. However, there was no exothermic reaction at 970°C. The endothermic reaction reaches its maximum intensity at about 520°C. It absorbs 100 calories per gram of air dried (65°C) material.

The values for the interval specific heats of Missouri diaspore clay from 0 to t°C are shown in Table VII.

12. Oil Shale As a representative of a class of material which contains a large amount of carbonaceous matter, oil shale was selected. This material was obtained from the Oil Shale

Laboratory, U. S. Bureau of Mines, Boulder, Colorado. It has the chemical composition shown in Table VI.

An exothermic reaction starts at about 160°C and extends to about 675°C. Any water that is in the shale is being driven off over this period and is absorbing heat. Also, there is bound to be more or less distillation of the volatile matter and of course heat is absorbed in this process. On the other hand, the volatile matter is ignited by the heat of the furnace and burns quite vigorously, thereby evolving heat. The sum total of the endothermic and exothermic reactions is 150 calories evolved per gram of air dried (65°C) material. After this violent exothermic process, the shale rises uniformly in temperature as heat is added until it reaches about 750°C, when another exothermic process begins and extends to about 950°C. This reaction is due, in all probability, to the burning out of the fixed carbon and amounts to 34 calories per gram of the air dried (65°C) shale.

The shale sample at the peak of the first exothermic process was almost 300°C hotter than the reference material and, of course, rapidly lost heat by radiation to the furnace and by conduction down the thermocouple leads. This was, of course, of such a nature that the sample soon cooled to near the furnace temperature after the exothermic process was completed; thus, the effect of the evolved heat on the specific heat values was lost. If the material were in a system such as to prevent the loss of this excess heat, the value of the exothermic processes would have to be subtracted from the calory-temperature curve (Fig. 13), in order to find the number of calories required to heat it to any given temperature. That is, the upper curve section should be projected from the point *B*.

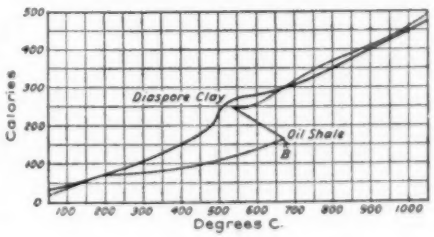

FIG. 13.

The oxidation was so severe that a thermocouple never survived over a single heat.

The values for the interval specific heats of Colorado oil shale over the interval 0 to t°C are shown in Table VII.

13. Firebrick Body No. 3

This material was kindly placed at the author's disposal by the Ashland Fire Brick Co., Haywood, Ky. It is representative of a high grade fire brick manufactured from Kentucky clays. It has the chemical composition shown in Table VI.

Qualitatively, this material showed the same behavior on heating as did the kaolins, exhibiting an endothermic reaction in the neighbor-

hood of 500°C and an exothermic reaction at about 956°C. However, the reactions were much less intense. The thermal behavior of this material on heating more nearly approximates that of ball clay than that of kaolin. The endothermal process, beginning at 300°C and extending to 600°C, absorbs 62 calories per gram of air dried (65°C) material. The exothermal process which takes place at about 956°C evolves 6 calories per gram of air dried (65°C) material.

The values for the interval specific heats of this firebrick body over the interval 0 to $t°$ are shown in Table VII.

It is to be recalled that this firebrick body (as were the four following firebrick bodies) was one of those investigated by the Ceramic Experiment Station of the U. S. Bureau of Mines in the investigation of the distribution of heat in refractory kilns.[1] This material is similar to that used in Tests A and B, Test Serial Numbers 5 and 6, Table I. Referring to Table I, one sees that 16.6 and 23.6% of the total heat in the fuel was used, respectively, to heat the brick in Tests A and B to their finishing temperature. These values were calculated from specific heat values of 0.264 for Test A and 0.265 for Test B. This gives an unaccounted for loss of 23.4 and 22.8% of the total heat available in the fuel used in Tests A and B respectively. The initial and finishing temperature in Test A was 33°C and 1192°C respectively. The initial and finishing temperature in Test B was 24°C and 1209°C respectively.

By extrapolating the curve in Fig. 14 to 1209°C it is evident that 509 calories and 517 calories are required to heat one gram of this material from 0°C to the finishing temperature, 1192°C and 1209°C respectively, in Tests A and B. On subtracting 10.8 (which is the number of calories required to heat one gram of this material from 0°C to 33°C, the initial temperature in Test A) from 509 and 7.8 (which is the number of calories required to heat one gram of this material from 0°C to 24°C, the initial temperature in Test B) from 517, it is evident that 498.2 calories and 509.2 calories are respectively required to heat this firebrick body over the temperature intervals employed in Tests A and B. This gives 0.432 and 0.430 as the specific heat of this material over the temperature interval employed in Tests A and B respectively. From these interval specific heats, it is calculated that 27.2% and 38.3% of the available heat in the fuel was used to actually heat the brick in Tests A and B respectively. This gives an unaccounted for loss of heat of 13 instead of 23.4 in Test A and 8.2 instead of 22.8 in Test B.

Thus, it is apparent that our ceramic kilns are considerably more efficient users of fuel than we have ordinarily supposed them to be. Also, it is apparent that the method of mixtures gives interval specific

[1] *Loc. cit.*

heat values which are entirely too low for a large portion of ceramic materials and bodies.

14. Firebrick Body No. 5

This material was kindly placed at the author's disposal by the Chicago Retort and Fire Brick Co., Ottawa, Ill. It is representative of the stiff-mud brick made in that district. It has the chemical composition shown in Table VI.

This material undergoes an endothermic reaction which begins at about 340°C, reaching its maximum intensity at 550°C. This endothermal process absorbs 65 calories per gram of air dried (65°C) material. An exothermic reaction takes place at about 931°C which evolves 10 calories per gram of air dried (65°)C material.

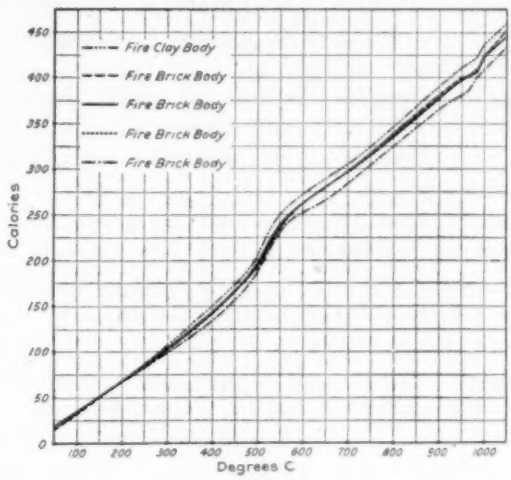

FIG. 14.

The values for the interval specific heats of this firebrick body over the interval 0 to t°C are shown in Table VII.

This material is similar to that used in Tests A and B, Test Serial Numbers 9 and 10, Table I. Referring to Table I, one sees that 23.8 and 22.0% of the total heat in the fuel was used, respectively, to heat the brick in Tests A and B to their finishing temperature. These values were calculated from specific heat values of .264 for Test A and .262 for Test B. This gives an unaccounted for loss of 18.7 and 29.6% of the total heat available in the fuel used in Tests A and B respectively. The initial and finishing temperature in Test B was 33 and 1148°C respectively.

By extrapolation of the curve in Fig. 14 according to the procedure outlined for firebrick body No. 3, it was found that 37.5 and 34.8% of the total heat available in the coal was really used to heat the brick in Tests A and B to their respective finishing temperatures. This gives an unaccounted for loss of heat of 5.2 instead of 18.7 in Test A and 17.0 instead of 29.6 in Test B. The large unaccounted for heat loss in Test B is due to lack of proper temperature measurements in the bottom of the kiln.

15. Firebrick Body No. 4

This material was kindly placed at the author's disposal by the Charles Taylor and Sons Co., McCall, Ky. It has the chemical composition shown in Table VI.

This material undergoes an endothermic reaction which begins at about 300°C and extends to about 585°C, reaching its maximum intensity at 553°C. This endothermal process absorbs 60 calories per gram of air dried (65°C) material. An exothermic reaction takes place at about 956°C which evolves 8 calories per gram of air dried (65°C) material.

The values for the interval specific heats of this firebrick body over the interval 0 to t°C are shown in Table VII.

This material is similar to that used in Tests A and B, Test Serial Numbers 7 and 8, Table I. Referring to Table I, one sees that 26.3 and 27.7% of the total heat in the fuel was used, respectively, to heat the brick in Tests A and B to their finishing temperatures. These values were calculated from specific heat values of 0.263 for Test A and 0.266 for Test B. This gives an unaccounted for loss of 12.6 and 13.6% of the total heat available in the fuel used in Tests A and B respectively. The initial and finishing temperatures in Tests A and B were 29°C and 1152°C, and 24°C and 1213°C respectively.

By extrapolation of the curve in Fig. 14 according to the procedure outlined for firebrick body No. 3, it was found that 42.8 and 44.5% of the total heat available in the fuel was really used to heat the brick in Tests A and B to their respective finishing temperatures. This gives an unaccounted for loss of heat of -3.5 instead of 12.6 in Test A and of -3.3 instead of 13.2 in Test B.

16. Firebrick Body No. 1

This material was kindly placed at the author's disposal by the Brooklyn Fire Brick Works, Brooklyn, N. Y. It is representative of a New Jersey fireclay brick containing a high percentage of grog. It has the chemical composition shown in Table VI.

This material undergoes an endothermic reaction which begins at about 250°C, reaching its maximum intensity at 543°C. This endothermal process absorbs 67.5 calories per gram of air dried (65°C) material. An exothermic reaction takes place at about 956°C which evolves 9.5 calories per gram of air dried (65°C) material.

The values for the interval specific heats of this firebrick body over the interval 0 to t°C are shown in Table VII.

This material is similar to that used in Tests A and B, Test Serial Numbers 1 and 2, Table I. Referring to Table I, one sees that 19.4 and 15.7% of the total heat in the fuel was used, respectively, to heat the brick in Tests A and B to their finishing temperature. The values were calculated from specific heat values of .263 for Test A and .259 for

Test B. This gives an unaccounted for loss of 8.0 and 14.8% of the total heat available in the fuel used in Tests A and B respectively. The initial and finishing temperature in Test A was 16°C and 1172°C respectively. The initial and finishing temperature in Test B was 24°C and 1080°C respectively.

By extrapolation of the curve in Fig. 14, according to the procedure outlined for firebrick body No. 3, it was found that 32.1 and 26.4% of the total heat available in the fuel was really used to heat the brick in Tests A and B to their respective finishing temperatures. This gives an unaccounted for loss of heat of −4.7 instead of 8.0 in Test A and 4.3 instead of 14.8 in Test B.

17. Firebrick Body No. 2 This material was kindly placed at the author's disposal by the Kier Fire Brick Co., Salina, Pa. It is representative of the best of the Clarion flint fireclay brick. It has the chemical composition shown in Table VI.

This material undergoes an endothermic reaction which begins at about 360°C and extends to about 600°C, reaching its maximum intensity at 550°C. This endothermal process absorbs 55 calories per gram of air dried (65°C) material. An exothermic reaction takes place at about 956°C which evolves 9.5 calories per gram of air dried (65°C) material.

The values for the interval specific heats of this firebrick body over the interval 0 to t°C are shown in Table VII.

This material is similar to that used in Tests A and B, Test Serial Numbers 3 and 4, Table I. Referring to Table I, one sees that 16.5 and 17.3% of the total heat in the fuel was used, respectively, to heat the brick in Tests A and B to their finishing temperatures. The values were calculated from specific heat values of .262 for Test A and .266 for Test B. This gives an unaccounted for loss of 10.6 and 16.2% of the total heat available in the fuel used in Tests A and B respectively. The initial and finishing temperature in Test A was 20°C and 1168°C respectively. The initial and finishing temperature in Test B was 29°C and 1218°C respectively.

By extrapolation of the curve in Fig. 14, according to the procedure outlined for firebrick body No. 3, it was found that 27.6 and 28.9% of the total heat available in the fuel was really used to heat the brick in Tests A and B to their respective finishing temperatures. This gives an unaccounted for loss of heat of −.3% instead of 10.6% in Test A and of 4.9% instead of 16.2% in Test B.

Further Investigations

Since knowledge of the specific heats of ceramic bodies greatly facilitates the ease with which firing efficiency, various types of kilns,

and methods of firing can be compared as well as presenting the data absolutely essential for heat balances where all factors are measured (as is strikingly illustrated in the case of the U. S. Bureau of Mines investigation into the distribution of heat in refractory kilns), it seems desirable to have the interval specific heats of as many ceramic materials and bodies determined as is practicable. From a scientific standpoint, it is desirable to have the interval specific heats of almost every known material. Therefore, the substances available for specific heat determinations and whose values are desired is practically unlimited.

The determinations made in this investigation extend over the range 0° to about 1050°C. It would be highly desirable if future determinations could be carried up to as high as 1500°C or thereabouts. It is highly desirable that future investigators determine the interval specific heats and thermal processes not only for single materials but also for mixtures, including all types of ceramic bodies. At higher temperatures the thermal processes will, undoubtedly, be quite complex and intensely interesting, especially in case of the bodies.

The determining of the actual quantitative figures for the various thermal processes which a material or body undergoes on heating is a distinct scientific achievement and it is to be hoped that further work along this line will be carried out in the near future. If such investigations are carried out, it would present a much more comprehensive insight into the behavior of a substance undergoing heating if the temperature measurements were made every 5°C instead of about every 50°C as was done in the present investigation.

Conclusions

In the way of general conclusions, the following might be said:

1. All kaolins undergo an endothermic process in the neighborhood of 575°C which amounts to about 100 calories per gram of clay.

2. All kaolins undergo an exothermic process in the neighborhood of 960°C which amounts to about 25 calories per gram of clay.

3. It requires about 500 calories to heat one gram of any kaolin from 0 to 1000°C, the specific heat over this interval being about 0.5.

4. All firebrick bodies undergo an endothermic process in the neighborhood of 550°C which amounts to about 55 calories per gram of body.

5. All firebrick bodies undergo an exothermic process in the neighborhood of 950°C which amounts to about 9 calories per gram of body.

6. It requires about 510 calories to heat one gram of any firebrick body from 25–1200°C, the specific heat over this interval being about 0.433. The actual amount of heat will, of course, depend upon the

amount of grog present, the larger the amount of grog the less the heat required.

7. Ball clays undergo an endothermic reaction in the neighborhood of about 550°C which amounts to about 90 calories per gram of clay.

8. Ball clays undergo a slight exothermic reaction in the neighborhood of 975°C which amounts to about 5 calories per gram of clay.

9. It requires about 450 calories to heat one gram of ball clay from 0°–1000°C, the specific heat over this interval being about .45.

10. Diaspore clays undergo an endothermic process in the neighborhood of 525°C which amounts to about 100 calories per gram of clay.

11. Diaspore clays undergo no exothermic process up to 1050°C.

12. It requires about 450 calories to heat one gram of diaspore clay from 0°–1000°C, the specific heat over this interval being about 0.45.

In the way of specific conclusions, the following might be said:

1. About 487.5 calories are required to heat one gram of air dried (65°C) A-1 English china clay from 0°–1048°C, the specific heat over this interval being 0.465. This clay undergoes an endothermic reaction at about 550°C and an exothermic reaction at 970°C which amount to 123 and 35 calories, respectively, per gram of air dried material.

2. About 505.4 calories are required to heat one gram of air dried (65°C) North Carolina kaolin from 0–1046.5°C, the specific heat over this interval being 0.483. This clay undergoes an endothermic reaction at about 550°C and an exothermic reaction at 970°C which amount to 150 and 40 calories, respectively, per gram of air dried material.

3. About 500.7 calories are required to heat one gram of air dried (65°C) Delaware kaolin from 0–1036.8°C the specific heat over this interval being 0.483. This clay undergoes an endothermic reaction at about 550°C and an exothermic reaction at 975°C which amount to 118 and 32 calories, respectively, per gram of air dried material.

4. 500 calories are required to heat one gram of air dried (65°C) Georgia kaolin from 0–1022.2°C, the specific heat over this interval being 0.488. This clay undergoes an endothermic reaction at about 550°C and an exothermic reaction at 980°C which amount to 127.5 and 22.5 calories, respectively, per gram of air dried material.

5. About 530.2 calories are required to heat one gram of Florida kaolin, air dried at 65°C, from 0–1044.9°C, the specific heat over this interval being .507. This clay undergoes an endothermic reaction at about 550°C and an exothermic reaction at 980°C which amount to 122.5 and 10 calories, respectively, per gram of air dried material.

6. About 480.0 calories are required to heat one gram of Kentucky ball clay, air dried at 65°C, from 0–1042.7°C, the specific heat over this interval being .462. This clay undergoes an endothermic reaction

at about 540°C and an exothermic reaction at 980°C which amount to 90 and 5 calories, respectively, per gram of air dried material.

7. About 271.7 calories are required to heat one gram of air dried (65°C) rose quartz from 0–1039.7°C, the specific heat over this interval being 0.261.

8. About 305.0 calories are required to heat one gram of air dried (65°C) feldspar from 0–1040.8°C, the specific heat over this interval being 0.293.

9. About 268.2 calories are required to heat one gram of air dried (65°C) magnesia spinel from 0–1042.2°C, the specific heat over this interval being 0.257.

10. About 465.0 calories are required to heat one gram of air dried (65°C) Missouri diaspore clay from 0–1043.7°C, the specific heat over this interval being 0.445. This clay undergoes an endothermic reaction at about 550°C which amounts to 100 calories per gram of air dried material.

11. It requires about 300 calories to heat one gram of air dried (65°C) Colorado oil shale from 0–1050°C, the specific heat over this interval being about 0.285. This clay undergoes an exothermic reaction at about 300°C and an exothermic reaction at about 800°C amounting to 150 and 34 calories, respectively, per gram of air dried material.

12. About 441 calories are required to heat one gram of the air dried (65°C) firebrick body No. 3 from 0–1050°C, the specific heat over this interval being 0.420. This body undergoes an endothermic reaction at about 550°C and an exothermic reaction at 956°C which amount to 62 and 6 calories, respectively, per gram of air dried material.

13. About 430 calories are required to heat one gram of air dried (65°C) firebrick body No. 5 from 0–1050°C, the specific heat over this interval being .409. This body undergoes an endothermic reaction at about 550°C and an exothermic reaction at 932°C which amount to 65 and 10 calories, respectively, per gram of air dried material.

14. About 440 calories are required to heat one gram of the air dried (65°C) firebrick body No. 4 from 0–1050°C, the specific heat over this interval being .418. This body undergoes an endothermic reaction at about 550°C and an exothermic reaction at 957°C which amount to 60 and 8 calories, respectively, per gram of air dried material.

15. About 450 calories are required to heat one gram of air dried (65°C) firebrick body No. 1 from 0–1050°C, the specific heat over this interval being 0.428. This body undergoes an endothermic reaction at about 550°C and an exothermic reaction at 956°C which amount to 67.5 and 9.5 calories, respectively, per gram of air dried material.

16. About 443 calories are required to heat one gram of the air dried (65°C) firebrick body No. 2 from 0–1050°C, the specific heat

over this interval being 0.423. This body undergoes an endothermic reaction at about 550°C and an exothermic reaction at 956°C which amount to 55 and 7 calories, respectively, per gram of air dried material.

In closing the author wishes to express his gratitude to Arthur S. Watts, Head of the Department of Ceramic Engineering, Ohio State University, and G. A. Bole, Superintendent of the Ceramic Experiment Station, U. S. Bureau of Mines, under whose joint direction the work was carried out, for their many helpful suggestions and untiring interest in the work and problems that arose during the course of the investigation.

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Volumes 2, 5, 8, 9, 10, 11, 12, 14, 18 and 19 of the *Transactions of the American Ceramic Society* are out of print. As we have received several requests for these numbers $5.00 will be paid for each copy on receipt in the Secretary's office.

The January and June, 1923 and the January, February, 1924 issues of the Journal are also out of print; 60 cents will be paid for each copy received by

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CERAMIC ABSTRACTS

Compiled by the

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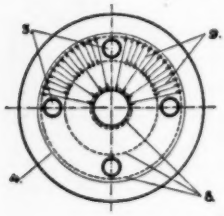
Abrasives

PATENTS

Antislip surface and method of making the same. FRANK J. TONE AND MINER L. HARTMANN. U. S. 1,567,772, Dec. 29, 1925. An antislip floor or tread surface having embedded therein abrasive grains, whose surfaces have been provided with a roughening coating before embedding.



Artificial-stone abrasive wheel. HERMANN AMOS. U. S. 1,570,664, Jan. 26, 1926. An abrasive wheel for the production of wood powder, made of artificial stone and adapted to be mounted on a shaft between clamping plates, said wheel comprising struts embedded in the artificial stone parallel to the axis of the wheel at a distance from said axis not exceeding the radius of the clamping plates.

Abrasive article and method of making the same. MINER L. HARTMANN. U. S. 1,573,061, Feb. 16, 1926. An abrasive article having voids contg. a finely divided solid lubricating mat. which is infusible under the ht. normally created by the abrasive action and a binder for the lubricant, substantially as described.

Method of making abrasive articles. MINER L. HARTMANN. U. S. 1,573,400, Feb. 16, 1926. In the process of making bonded abrasive articles, the steps consisting in adding to a raw mixt. of abrasive grains and bond, comminuted non-volatile organic particles which do not have a tendency to swell up during firing, pressing the mixt. to the desired shape, and subsequently effecting removal of the organic particles by firing the shaped article.

Siliceous alkaline-earth product and process of making the same. ROBERT CALVERT. U. S. 1,574,363, Feb. 23, 1926. A finely divided product comprising the product of heating a mixt. of finely divided diatomaceous earth, and hydroxide of an alkaline earth metal, and water.

Art

Industrial potter craftsmen. EDMUND DEF. CURTIS. *Bull. Amer. Ceram. Soc.*, **5** [3], 177–79(1926).—The questions of getting more trained artists into the industry and of making it more possible for potter craftsmen to earn decent livings are discussed. The necessary training is outlined, both artistic and tech. A small shop must be developed. The field should be charted so the student can specialize in work that appeals to him. Reprints should be made available as part of his equipment. More publicity and a circulating library of especial interest and value to the craftsmen are urged.

E. J. V.

Coördination of art, science, and practice. M. ELIZABETH COOK. *Bull. Amer. Ceram. Soc.*, **5** [3], 179–82(1926).—A plea is made for the recognition of art in connection

with the teaching of ceram. A high degree of scien. knowledge of ceram. has been reached but the artistic side has been neglected. The ideal, for a ceramist, is to equip himself with the dual knowledge of the art and science of clay and seek the field in which to "practice." Other industries are giving constructive training in the art connected with them as well as the science. Using the traveling exhibitions arranged by the Amer. Federation of Art as examples to follow, cannot similar exhibitions of ceram. masterpieces be shown at ceram. eng. coll., with full explanations of every feature of the exhibition? E. J. V.

A "reaction" to a visit to the ceramic sections of the international exposition at Paris, June, 1925. MARY G. SHEERER. *Bull. Amer. Ceram. Soc.*, **5** [3], 182–85 (1926).—The greatest reaction to the Paris Exposition is in relation to the unusual coöperation between science and art, and the industry and art of ceram. shown by the products of Danish and Swedish factories. The best ceram. artists are given full choice of any mat. produced in these factories to fully express themselves. This produces a great diversity of style and of mat. from one factory, but it has proved that individuality and beauty are highly practical. Americans are developing a greater appreciation of art though we are further behind in ceram. art than many others. The art trend is toward the unconventional, directness and simplicity being the main features. E. J. V.

Report of the ceramics of the international exposition at Paris, 1925. ADELAIDE ALSOP ROBINEAU. *Bull. Amer. Ceram. Soc.*, **5** [3], 185–90(1926).—The attention of Amer. manuf. is called to the fact that in France and other European countries all potters of any ability are being employed as directors or designers for some manuf. of ceram. Four points to be considered by Amer. ceram. industries and potters are: (1) ceram. used sculpturally and architecturally, (2) ceram. vases for use and cabinet, (3) ceram. figurines and novelties, (4) ceram. tableware. The examples of these points are given in detail as seen in the various exhibits at the exposition. The trend of art is shown and a plea is made for Americans to show more originality in their designs rather than copy the work of others. The point of greatest interest to manuf. here is that the best artists and designers are being employed not only to design and execute models for indus. reproduction, but to superintend the output and try out new ideas. Foreign manuf. are showing a much greater willingness to "take a chance" than are our own. E. J. V.

Note on Whieldon pottery. W. EMERY. *Trans. Ceram. Soc.* (Eng.), **24** [4], 339–46 (1924–25).—The majority of specimens of Whieldon ware possess artistic beauty and reach a high technical stand. Thomas Whieldon was born in September, 1719. Josiah Wedgwood was a junior partner with Whieldon for the five years 1754–59. The types of ware made by Whieldon were: slip-decorated ware, salt-glazed ware, black- and red-glazed ware, surface agate, solid agate, mottled glazed, and that beautiful ware known as melon, pineapple and cauliflower. See *Ceram. Abs.*, **8** [9], 241 (1925). R. F. S.

Muffle colors. W. FUNK. *Trans. Ger. Ceram. Soc.*, **6** [5], 221(1924).—A discussion of German *vs.* foreign muffle colors and an explanation of the peculiarities of some colors. F. A. W.

Glasses and glazes in ancient Assyria. ANON. *Pottery Gaz. and Glass Trade Rev.*, **51** [583], 87–89(1926).—Information is given concerning the glasses, enamels and glazes of the ancient Assyrians. This information is taken from Assyrian cuneiform tablets which have recently been deciphered by R. Campbell Thompson, of Oxford. Approx. formulas, source of mats. and methods of prepn. are given. R. E. G.

Swedish manufacturers and artists developing the art of making glass. ANON. *Nat. Glass Budget*, **41** [41], 16(1926).—Reproduction of an article entitled "An art born of fire," by E. Wettergren in the Amer. Scand. Rev., Jan., 1926. A long article describing the development of an art glass indus. at Smaland, Sweden. F. G. J.

PATENT

Etching. WALTER ADDISON STRAW. U. S. 1,565,869, Dec. 15, 1926. A method of etching, which consists in applying an agent directly to the mat. to be etched, which agent alone will not cause etching, and then immersing the object to be etched into an acid which will not alone cause etching, the mixt. of the two agents forming a compd. which will cause etching.

Cement, Lime, and Plaster

Vitrified sewer pipe joined with petrolastic cement. ANON. *Clay Worker*, **85** [1], 31(1926).—An illustrated description of the use of "Petrolastic" cement for joining sewer pipe. This cement may be made to form a tight joint, even if the pipe is partly submerged. R. E. G.

A non-corrosive cement. ANON. *The Chemical Age*, **13** [330], 381(1925).—Corrosion of iron in magnesium oxychloride cements is attributed to chem. reaction of iron with the chloride. To counteract the corrosion, the chlorine is combined with a metal having at least as great an affinity for it as the metallic iron. Ferrous chloride is used with satisfactory results. E. E. P.

New standard specification for cement. ANON. *The Chemical Age*, **13** [331], 403 (1925).—Report of a new Brit. standard specif. for Port. cement. Requirement of fineness limits residue on 180 by 180-sieve to 10%, min. tensile strength of neat cement after 7 days is 600 lbs. per sq. in., and of cement and sand, 325 lbs. per sq. in. The max. initial setting time of normal cement is 30 min. and of quick-setting cement, 5 min. E. E. P.

Hardening of cement. H. LECHATELIER. *Jour. Soc. Chem. Ind.*, **45**, 61(1926).—At the meeting Jan. 11 of the Fr. Acad. Sci., LeC. described Baykoff's theory of the hardening of hydraulic cement, and drew an analogy with the setting of plaster. H. H. S.

The hydration of lime. W. G. WHITMAN AND G. H. B. DAVIS. *Ind. Eng. Chem.*, **18** [2], 118(1926).—This paper presents a study of the effect of the various hydration methods on the properties of hydrated lime. The 3 most important variables are the ratio of water to lime, the temps. of hydration, and the deg. of agitation. The quality of the hydrated product was evaluated by testing its rate of reaction with acid and its rate of settling in water and by microscopic examn. In general, the relative rating of quality by any one of these methods checks closely with the ratings by the other two. The best product was prepd. by hydrating quicklime with a large excess of water in boiling soln. Hydration with the theoretical amt. of water or with water vapor gives a coarse inferior hydrate. F. G. J.

Annual report of the chemical director. G. J. FINK. 7th Ann. Convention, Nat. Lime Assn., Tech. papers and addresses, p. 37, May, 1925.—The Assn. maintains a lab. where four men are employed. Much of the time has been spent on the problem of quick-setting plaster, the other activities being properties of limes, new uses, and ed. promotion. One man's time is almost entirely devoted to analytical service for members. F. G. J.

Factors governing lime kiln capacity and fuel economy. V. J. AZBE. 7th Annual convention, Nat. Lime Assn., Tech. papers and addresses, p. 37, May, 1925.—Attempts to establish a standard of comparison and to outline on what these standards are based. Studies the subject under the foll. headings:—Actual fuel-lime ratios obtained in various plants. Heat distribution in theoretical kiln. Kiln efficiency rating. Effect of excess air on lime kiln efficiency. Incomplete combustion. Heat loss by radiation. Kiln gas anal. Results of kiln gas anal. tests made at different plants. Reduction of lime kiln efficiency during drawing period. Lime kiln heat transfer. Kiln capacity,

rating, proper kiln propn. and operation. Methods of firing. Lime kiln running periods and lime kiln refracs. Closure. F. G. J.

Studies of bond between concrete and steel. DUFF A. ABRAMS. Structural Materials Research Lab., *Bull.*, **17**.—Bond tests were made by applying a pull on one end of 1-in. plain round steel bars embedded axially in 8 by 8-in. concrete cylinders; parallel compression tests were made on 6 by 12-in. concrete cylinders. The concrete covered a wide range in quantity of mixing water, cement, and size and grading of aggregate. Tests were made at ages of 7 days to 1 year. 735 pull-out bond tests and 735 parallel compression tests were made. The principal conclusions from the tests are: (1) slipping of the bar began at a bond stress of about 10 to 15% of the compressive strength of the concrete, but considerable additional load was taken before the ultimate bond resist. was reached. (2) An end slip of bar of 0.0005 in. occurred at 55 to 60% of the max. bond. For mixts. leaner than 1–1, the max. bond was about 24% of the compressive strength of the concrete and came at an end slip of about 0.01 in. regardless of the charac. of the concrete. (3) Bond and compressive strength increased with age of the concrete from 7 days to 1 year. For 1–5 concrete of water-ratio 0.88, the bond at 1 year was 134% of the 28-day value and the compressive strength was 148%. (4) Bond responded to changes in water-ratio of the concrete in much the same way as compressive strength; increase in water-ratio due to use of wetter concrete, less cement, or an excess of fine aggregate, resulted in material reductions in both bond and compressive strength. (5) For mixt. richer than 1–1 the bond fell off probably due to the greater vol. changes during hardening, which is charac. of such mixts. (6) The use of 4% of the 28-day compressive strength of concrete as the working stress in bond for plain bars, as specified by the Joint Comm., is justified; this gives a factor of safety of about 2½ to 3 against first slip. (7) The use of crude oil to replace mixing water, in general, caused a reduction in both bond and compressive strength of concrete due probably to the lubricating effect of the oil. Replacing cement with hydrated lime also decreased the compressive strength and bond about 1.2% for each 1% of hydrated lime in terms of vol. of cement or about 2% for each 1% by wt.

A new quick-hardening slag cement. P. PRÉVOST. *Chimie et industrie.* **Special No.,** 337–38 (Sept. 1925).—"Louve" brand cement, manufd. by the Société Générale des Chaux et Ciments, has the following av. compn.: combined SiO_2 24.2, sand 1.2, Al_2O_3 13.8, Fe_2O_3 1.6, CaO 46.3, MgO 2.4, SO_3 0.9, undetd. 9.6%; fineness, 1% held on a 75-mesh (per in.) sieve, 10% held on a 175-mesh sieve; apparent d. 0.880, deformation at 100° 1 mm. Setting begins in about 5 hrs. and is complete in 8–15 hrs. Results of tests are given showing it to have considerably higher tensile and crushing strengths after 1, 2, 7, 28 and 90 days than slag and artificial Portland cements meeting the specifications of the City of Paris. The process of manuf. is not disclosed. (*C. A.*)

Modern quick-hardening cements. C. T. STEPHENS. *Commonwealth Engineer*, **13,** 89–91(1925).—S. gives a short general discussion of high-alumina cements and rapid-hardening Port. cements. Differences in compn., manuf. and strength of resulting products are stated. A few estimates upon cost and some information concerning the use of these products in buildings, roads and concrete pipes, are included. (*C. A.*)

Results of tests with alcement Lafarge. A. F. R. LUND. *Teknisk Ukeblad*, **72,** 324–37, 335–40, 350–52(1925).—Alcement, manufd. by the S. té A. me des Chaux & Ciments de Lafarge et du Teil, France, had the following compn.: SiO_2 8.68, insol. 3.49, Al_2O_3 and TiO_2 41.53, FeO 6.38, CaO 40.96, MgO 0.69, SO_3 0.07, hygroscopic water 0.05, and increase in wt. on ignition 0.44%. It was compared with a Portland cement of normal compn. The setting properties of the alcement were normal. Notwithstanding

an increase in temp. of 15° the setting time was not reduced noticeably even with an initial temp. of water and air of 25° or even 30°. The soundness was satisfactory. The hardening of the alcement was extremely quick. The major part of the ultimate strength was reached in 24 hrs. After 28 days the tensile strengths of the two sand mortars were nearly alike, only with a 10% difference in favor of the alcement, but the crushing strength of the latter was nearly twice that of the Portland cement mortar. In concrete the superiority in crushing strength of the alcement was still greater. Humic acids in the sand have only a small influence upon the quality of this mortar. It was very resistant to fire and frost, but less so to rapid cooling in water from a temp. of 1100°. Alcement mortars showed slightly greater resistance to wear. Large test specimens of concrete and reinforced concrete from the two cements all proved great and general superiority of the alcement. (*C. A.*)

Plastic magnesia. O. C. RALSTON, R. D. PIKE, AND L. H. DUSCHAK. Bur. Mines, *Bull.*, **236,** 107 pp. (1925).—Plastic magnesia is defined as a caustic magnesia adaptable to forming Mg oxychloride cement when mixed with a $MgCl_2$ soln. of proper consistency. Full discussion includes: the constitution of Mg cements, the rate of thermal decompn. of natural $MgCO_3$ and $CaCO_3$, calcination of magnesite for plastic magnesia, methods of judging the quality, recarbonating free lime in burnt magnesia and dolomite, the effect of exposure on plastic magnesia, and the behavior of SiO_2 during the firing of magnesia. (*C. A.*)

PATENT

Aluminous cement. U. B. VOISIN. Brit. 233,698, May 6, 1924. Equal vols. of medium hydraulic lime or limestone and bauxite are ground, mixed, briquetted and fired at 1200–1500° for 12 hrs. to obtain a hard-grinding black clinker which after grinding sets in 2–3 hrs. By employing fat lime and slowing down the firing, a cement is obtained which sets almost immediately. (*C. A.*)

Enamel

Copper lined drier and quenching bucket keep enamel clean. ANON. *Ceram. Ind.*, **6** [2], 154–55 (1926).—A description of the enamel department of the Dayton Porcelain and Enameling Co. is given. The quenching tank and drier are lined with copper in order to cut down possibility of specks. The two furs. used in firing the ware have exceptionally low fuel consumption, due to heavy insulation. R. E. G.

What affects efficiency of wet grinding enamels in ball mills. R. D. COOKE. *Ceram. Ind.*, **6,** 183–84 (1926).—Wet grinding enamel in pebble mills was studied. The variable factors considered were: (1) speed of rotation of the mill, (2) propn. of water to total charge, (3) size of charge, (4) quantity of pebbles, and (5) (as a corollary of (3) and (4)), the ratio of size of charge to quantity of pebbles. Each of these factors was varied independently of the others and the effects noted upon power, consumption, grinding time, and the labor per 1000 lbs. of enamel produced. The mill used was 54 inches in diameter and 47 inches long. The lining was of silex blocks, three inches thick. Power was furnished by a 7½ h.p., 220 volt, d.c. motor, through a variable speed cone pulley and suitable reducing pulleys. All frit was ground to the same degree of fineness. Standard conditions were: Pebbles, 1,500 lbs.; frit, 1,000 lbs.; water, 437.5 lbs.; other additions, 115 lbs.; and speed, 30 r.p.m. With these conditions the running time was 10.28 hours, the average power was 4.29 h.p. (elec.), and the labor of loading and discharging was 3 man-hours. The foll. table shows the condition which was varied, and the results, based on 1000 lbs. of enamel:

Variable	Mill hrs. per 1000	Kw. hrs. per 1000	Man hrs. per 1000	Variable	Mill hrs. per 1000	Kw. hrs. per 1000	Man hrs. per 1000
None.....	7.28	21.2	1.93	10% less water...	10.00	26.0	1.93
20 r.p.m.....	12.55	23.5	1.93	10% more water..	6.62	18.0	1.93
40 r.p.m.....	5.80	21.8	1.93	20% more pebbles	6.03	18.9	1.93
40% less enamel..	4.94	16.1	2.36	20% less pebbles .	9.82	23.5	1.93
40% more enamel.	14.21	33.2	1.75				

The ratio of pebbles to enamel was then kept constant and the total bulk of charge varied. The weight of pebbles was 1.4 times the wt. of enamel and water. The foll. table gives the results:

Charge lbs.	Mill hrs. per 1000	Kw. hrs. per 1000	Man hrs. per 1000	Charge lbs.	Mill hrs. per 1000	Kw hrs. per 1000	Man hrs. per 1000
2230.....	5.66	18.1	2.36	3600.....	4.98	17.5	1.96
2486.....	5.56	17.9	2.25	4285.....	4.85	18.2	1.85
3000.....	5.05	18.1	2.09				

From these results it seems that power required per 1000 lbs., is independent of the size of the charge. R. E. G.

Cause of inverse segregation. G. MASING. *Z. Metall.*, **17,** 251–57 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 994 (1925).—The phenomena which occur during cooling of a casting of an alloy are as follows: Crystn. of the primary dendrites starts at the surface of the mold, and these proceed to grow into the mass; as the temp. falls further, the dendrites shrink away from the sides of the mold, leaving hollow spaces which later, at the moment of expansion on solidification, are filled by the remaining liquid being forced into them. Thus the outer layers of the ingot are richer in the constituent of lower m.p. than the core. The conditions for the occurrence of this inverse segregation are: (1) a tendency for the primary crystals to grow in dendritic form; (2) a tendency for the formation of mixed crystals having zones of different compn., (3) a considerable difference in the compn. of the crystals first formed and the remaining liquid. H. H. S.

PATENTS

Rustproofing bath for iron and steel. JAMES H. GRAVELL. U. S. 1,572,354, Feb. 9, 1926. A bath for rustproofing comprising water, free phosphoric acid and monosodium phosphate which combining with pickling and foreign acids opposes the formation of a sludge.

Enamel metal shingle. FRANK M. BLAIR. U. S. 1,572,377, Feb. 9, 1926. A roof composed of a series of shingles, each with two longitudinal ribs and with a right angular down-turned base flange extending below the body of the shingle and having therein two notches, one of said notches receiving the rib of a shingle to the right and the other notch receiving the rib of a shingle to the left, said shingle to the right and said shingle to the left being held in contact with one another by said engagement.

Sheet-pickling method. JOHN B. TYTUS. U. S. 1,572,583, Feb. 9, 1926. A process for electrolytically treating iron or steel pieces which because of their width must be produced in short length, which consists in uniting the pieces end for end, feeding the band so formed through an electrolyte contg. suitable electrodes and establishing current connection with the band to convert it into an electrode.

Process for treating iron. WILLIAM J. DIEDERICHS AND ANSON HAYES. U. S. 1,574,376, Feb. 23, 1926. The process for the ht. treatment of castings from white cast iron which consists in (1) subjecting the casting to a temp. above the critical

temp. of the mat. for a period of from 15 min. to 5 hrs. or more but only until the iron carbide present is practically all absorbed in the solid soln., which means that in irons of commercial compn. the combined carbon is reduced to approx. .9%; (2) the cooling of the casting to a lower temp. in the neighborhood of the critical temp.; and (3) the cooling of the casting at a rate not less than about 7°C per hr.

Process for treating iron. WILLIAM J. DIEDERICHS AND ANSON HAYES. U. S. 1,574,377, Feb. 23, 1926. The process for the ht. treatment of castings from white cast iron which consists in (1) the subjecting of the casting to a temp. above the critical temp. of the mat.; (2) the cooling of the casting to a point considerably below the original critical temp. by quenching; (3) rehtg. the casting to a sufficient temp. to allow chem. and structural changes to progress; and (4) cooling the casting to a temp. sufficiently low that chem. and structural changes cease.

Glass

New leer cuts annealing time 50%. C. H. MODES. *Ceram. Ind.*, **6** [2], 145 (1926).—M. describes a new elec. leer used by the Ill. Glass Co. This leer is found to do 100% annealing in one-half the time and used only one-third of the usual space. R. E. G.

Plan for reclaiming 12% waste gases from glass tank. R. R. MEYER. *Ceram. Ind.*, **6** [2], 148–53 (1926).—A suggested system to reclaim 100 to 150 h.p. per ton of coal used in melting of glass, from waste heat. In most factories this heat could be used to good advantage in making steam for gas producers. R. E. G.

Producing clear fused quartz electrothermally. E. R. BERRY. *Chem. Met. Eng.*, **32**, 915–16 (1925).—After a brief historical sketch of the manuf. of fused quartz, the process recently perfected by the Gen. Elec. Co. is described. The author mentions the new gallium-in-quartz thermometer, for temps. up to 1000° C and compares it with mercury-in-glass thermometers. M. E. M.

Mechanical drawing of tubing. GEORGE GEHLHOFF. *Glastechn. Berichte*, **3** [6], 205–13 (1925).—The fabrication of glass rods and tubing by the old hand process is first taken up to better show the analogy it has to the mech. processes now being used. The principles of operation of the Danner and Philips types of mach. are gone over in considerable detail, discussing all factors. The actual process of manuf. used in a plant now in opern. is discussed, using photos to illustrate various points. Costs of manuf. are lowered with better quality of product. It is shown how successfully one can compete with the methods of their forefathers by changing to the mech. production. E. J. V.

Low pressure air and its uses in glassware. J. E. LISTER. *Glass Worker*, **45** [18], 17 (1926).—Reprinted from *Glass*, London, Eng. It is more economical to use a separate low press. air system for cooling workmen around furs. with a cold air douche and for cooling molds. F. G. J.

Fused quartz and metal gallium in high temperature thermometer. ANON. *Glass Worker*, **45** [17], 22 (1926).—The Thompson Research Lab. of the General Elec. Co. at Lynn, Mass. has developed a thermometer capable of registering over 1800° F. Instead of glass which would melt, it is made of clear fused quartz. Mercury would boil and explode the thermometer at these temps., so gallium, one of the rarer metals, is used. It melts at 100° F but can be cooled to 40° without solidifying. It boils at 3600° F. The thermometer permits of accurate high temp. readings. It is not yet on the market. F. G. J.

New tank possesses many advantages. ANON. *Nat. Glass Budget*, **41** [40], 3 (1926).—A description of a patented continuous glass mtg. tank put out by the Simplex Eng. Co. It was designed for making very high grade glass. The initial depth is only 18" and it will melt a T. on 7 sq. ft. of mtg. surface per 24 hrs. The fuel consumption

averages 8 to 10 M. cu. ft. natural gas or its equiv. per T. of glass. It is 15 to 25% cheaper to build than the conventional tank and the nature of the charge can be changed rapidly. F. G. J.

German optical glass combine. ANON. *Jour. Soc. Chem. Ind.*, **45,** 25 (1926).—An agreement has been entered into between Goerz of Berlin, Contessa-Nettel of Stuttgart, Ica, and Ernemann of Dresden, and Zeiss of Jena, for the better utilization of their means of production, and for common action in regard to purchase of raw mats. and semi-manufd. articles. H. H. S.

Modern resistance glasses. E. E. AYLING. *Jour. Soc. Chem. Ind.*, **45,** 7 (1926).—The durability of modern resist. glasses, such as Pyrex, Durosil, and Durex, to chem. reagents, to changes of temp., and to prolonged htg., was described. Various modern methods of testing durability, including those of the Natl. Phys. Lab., were given. The importance of resist. to prolonged htg. was shown in its application to thermometric work and the prevention of devitrification. An account of the way in which the results of now classic researches were weakened by the nature of the glasses used was given, and durability was explained in relation to the liberation of alkalis, catalysis, and hydrolysis. The state of the Brit. glass indus. during the war was outlined, and it was claimed that Brit. glass is now equal to the best that Ger. ever produced. H. H. S.

Clear fused quartz. E. R. BERRY. *Jour. Soc. Chem. Ind.*, **45,** 35–36 (1926).—Translucent, or common, fused quartz familiar in the lab. is not transparent owing to a multitude of bubbles. The difficulty of getting rid of these bubbles is increased by the high viscosity of the molten mass, and by the fact that quartz vaporizes well below its m.p., the loss by volatilization being 20% in 10 mins. By fusing quartz in vacuo, most of the bubbles are freed, and the remainder can be greatly diminished in vol. by increasing the press. on the molten mass to 1000–3000 lbs. per sq. in. A new thermometer, registering from 500–1000° C, was made by using gallium instead of mercury in a quartz capillary. H. H. S.

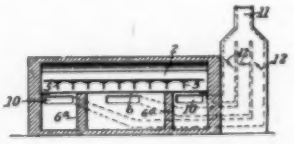
Operating conditions of Boetius glass furnaces. H. XHIGNESSE. *Chaleur et ind.*, **6,** 536–39 (1925).—A discussion of the opern. of this type of fur. showing its disadvantages and giving a heat balance observed in com. opern. (*C. A.*)

The electrolysis of soda-lime glass. M. J. MULLIGAN. *Trans. Roy. Soc. Can.*, Sec. III (3) **19,** 35 (1925).—The elec. migration of Ag from an Ag anode in aq. solns. into glass was observed. Ag from an aq. soln. of $AgNO_3$ diffused into glass at 100° without the use of the elec. current. (*C. A.*)

PATENTS

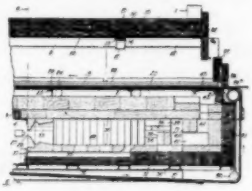
Glass-drawing apparatus. WILLIAM L. MONRO. U. S. 1,570,695, Jan. 26, 1926. In app. for drawing glass cylinders, a bait, a chamber adjacent the bait, and a nozzle of smaller cross sectional area than the chamber adapted for the discharge of air in jet form through the chamber and into the bait, the chamber having a substantially continuous wall at one side of the path of said air jet and having an opening opposite such wall, substantially as described.

Method and apparatus for annealing and cooling sheet glass. FREDERIC L. BISHOP. U. S. 1,570,822, Jan. 26, 1926. In the method of annealing and cooling sheet glass, the steps consisting in passing glass through a leer, passing streams of heated gaseous fluid through the leer above and below the glass and in contact therewith, and varying the cooling effect of at least one of said streams from side to side of the leer.



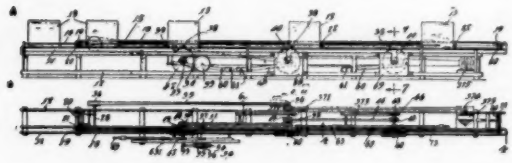
Manufacture of glass cylinders. WILLIAM L. MONRO, HENRY F. CLARK AND LONNIE J. PIERCE. U. S. 1,570,853, Jan. 26, 1926. In app. for drawing glass cylinders, a bait, a chamber above the bait through which air is supplied to the cylinder being drawn, having an air inlet opening which is of smaller cross-sectional area than and is adapted to discharge air in jet form into the chamber, said chamber being at least partially enclosed laterally of the air stream and having a venting opening, substantially as described.

Glass and article made therefrom. ARTHUR H. COMPTON. U. S. 1,570,876, Jan. 26, 1926. A glass resistant to the chem. action of vapors of metals of the sodium group, comprising boron oxide, and basic oxides including at least one alkali metal oxide, at least one of the following oxides, namely, calcium, barium, strontium or magnesium oxide, and aluminum oxide.



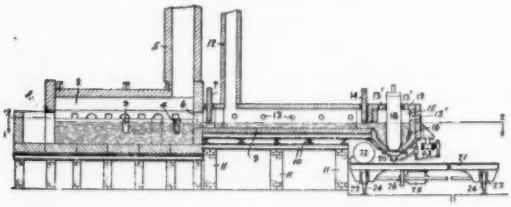
Method and apparatus for annealing glassware. VERGIL MULHOLLAND. U. S. 1,571,137, Jan. 26, 1926. The method of annealing glass ware, which comprises passing the ware through a tunnel, htg. the lower portion of the tunnel to cause upwardly moving convection currents, cooling the upper portion of the tunnel to cause downwardly moving convection currents, and independently regulating both the htg. and the cooling of said portions of the tunnel at intervals longitudinally thereof to control the rate of movement of said convection currents.

Machine for grinding glass plates. KARL A. WEBER. U. S. 1,571,985, Feb. 9, 1926. A mach. for grinding an edge of a glass plate comprising a line of support upon which the glass may be stood on edge in a substantially vertical position, means for guidingly maintaining it in such position, and grinding means moving in the line of feed of the glass and located substantially on a level with said line of support and onto which the glass moves and by which it is supported on edge while being ground.

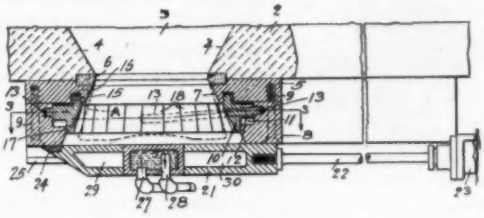


Gate for glass tanks. HALBERT K. HITCHCOCK. U. S 1,572,481, Feb. 9, 1926. The combination with a mtg. tank having an outlet at its forward end, of a gate mounted for vertical movement through the top of the tank, and adapted when lowered to cut off the flow of glass to said outlet, said gate comprising a lower water cooled portion and a portion of refrac. mat. lying thereabove.

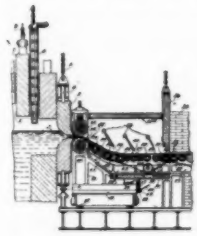
Method and apparatus for casting plate glass. FRANK E. TROUTMAN AND CHARLES H. CHRISTIE. U. S. 1,572,580, Feb. 9, 1926. The method of casting molten glass that comprises establishing a body of molten glass above a discharge outlet and then chilling the glass at the outlet to a predetd. thickness to cause the glass to issue slowly initially from the said outlet.



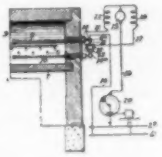
Casting plate glass. FRANK E. TROUTMAN AND CHARLES H. CHRISTIE. U. S. 1,572,581, Feb. 9, 1926. The method of controlling the discharge of glass from an outlet, that comprises applying a chilling instrument to said outlet, thereby causing the glass within said outlet to harden, withdrawing said instrument from said outlet, and loosening the hardened glass in said outlet by downwardly moving a member adjacent to said glass within said outlet. App. for casting plate comprising a glass receptacle having a downwardly opening outlet, an annular structure beneath said outlet having a downwardly movable inner portion, and a shear member adapted to be moved into and out of position beneath the opening defined by said annular structure.



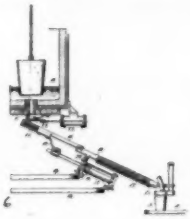
Glass. WILLIAM CHITTENDEN TAYLOR. U. S. 1,572,625, Feb. 9, 1926. The hereinbefore described process of modifying the colors due to metallic salts in borate glasses, which comprises adding a halogen.



Apparatus for making sheet glass. ROBERT L. CLAUSE. U. S. 1,572,468, Feb. 9, 1926. App. for forming sheet glass continuously in a sheet or ribbon from a body of molten glass, comprising a pair of cooled rolls contracting with said molten body of glass, and a table for receiving the glass and forwarding it, comprising a series of spaced rollers, a series of platens interspersed between the rollers having their upper surfaces substantially flat and filling the spaces between the rollers, and means for cooling the rollers and platens.

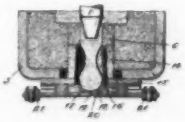


Method and apparatus for annealing and cooling sheet glass. FREDERIC L. BISHOP. U. S. 1,573,033, Feb. 16, 1926. In the method of annealing and cooling sheet glass, the steps consisting in passing sheet glass through a leer, passing gaseous fluid through the leer in streams above and below the glass, and adjusting the relative cooling effect of the streams to maintain a predetd. relative temp. condition between a plurality of points in the leer, substantially as described.



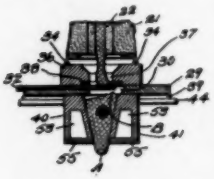
Glass-blowing device. CLAUDE W. PLEUKHARP. U. S. 1,573,273, Feb. 16, 1926. In a glass flowing mach. a charging vessel, a mold carrying device, an inclined chute arranged between, said chute having a reciprocating upper portion and a stationary lower portion, and a compressed air cylinder and piston for actuating the reciprocating portion.

Method of feeding glass to forming machines. LEO A. DREY. U. S. 1,573,635, Feb. 16, 1926. The method of delivering glass from a fur. to a mold, which consists in flowing glass on a support which contacts with only a portion of the batch and subjecting the free unsupported remaining portion of the batch to heat.

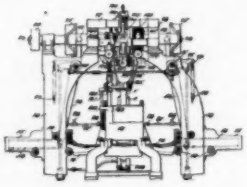


Apparatus for feeding glass into molds. LEO A. DREY. U. S. 1,573,636, Feb. 16, 1926. In an app. for gathering molten glass from a continuously flowing stream, comprising a supporting plate having a central opening therethrough,

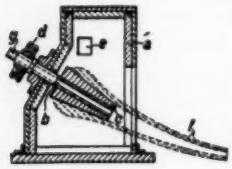
said opening being concentric with the stream of glass, a recess formed in the upper face of said plate, a knife slidably located in said recess, means for operg. said knife periodically across said opening for closing the same and severing the oncoming stream of glass, a bottomless cup composed of sep. members slidably secured to the underside of said supporting plate, and means for moving said sep. members to and from each other when the opening in the supporting plate is closed.



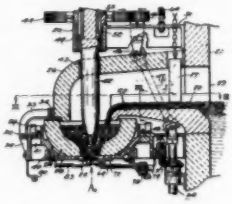
Feeding molten glass. KARL E. PEILER. U. S. 1,573,742, Feb. 16, 1926. App. for sepg. molten glass into mold charges, including a container for the glass having an outlet, severing means operg. periodically beneath the outlet, means for timing the suspension of successive gathers of glass beneath the outlet in timed relation to the opern. of the severing means, and means for varying the time of beginning of suspension period relative to the time of severing.



Method of and device for drawing tubes. RICHARD HIRSCH. U. S. 1,574,482, Feb. 23, 1926. A method which consists in forming tubular mass of molten glass having its two ends of different shapes and sizes in cross section, continuously drawing a tube from smaller end of said mass, continuously adding to the other end of said mass, and maintaining the respective ends of said mass in substantially their original shapes and sizes in cross section.



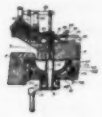
Apparatus for delivering charges of molten glass. LEONARD D. SOUBIER. U. S. 1,574,709, Feb. 23, 1926. The combination with a receptacle to contain molten glass having an outlet opening in the bottom thereof, means to rotate the receptacle about the vertical center line of said opening as an axis, a regulator projecting downward into the glass in the receptacle over said outlet, means to reciprocate said regulator toward and from the outlet and thereby control the discharge of glass through the outlet, a cutter mounted to rotate with said receptacle beneath said outlet, and automatic means operating in synchronism with the movements of said regulator to periodically actuate the cutter and thereby sever charges of glass issuing from said outlet.



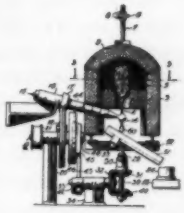
Process for manufacturing photographic glass pictures and the like with colored background. WERNER KIESLING. U. S. 1,574,156, Feb. 23, 1926. A process for the photomechanical mfg. of glass pictures and the like with colored background, wherein the transparent plate or the like is coated with a thin layer of chromate glue sol. in the cold, the coated side of the plate being exposed under a reticle negative, the unaltered glue being then removed from those portions of the plate which were protected from light during the exposure under the reticle negative, the exposed portions being then colored with a dye soln., and the entire coated side of the plate and especially those portions from which the light-sensitive layer has been removed being finally painted with another coloring substance for the production of the background.

Feeder for molten glass. KARL E. PEILER. U. S. 1,574,736, Feb. 23, 1926. A feeder for molten glass, comprising a rotatable gathering head, means for rotating

said head, and means for flowing molten glass upon said head, while rotating, whereby a layer of glass is accumulated around the head.



Method and apparatus for delivering molten glass. ENOCH THEODORE FERNGREN. U. S. 1,574,739, Feb. 23, 1926. The combination of a receptacle to contain molten glass, said receptacle provided with an outlet orifice, and automatic means to cause an equalization of temp. within the receptacle comprising mechanism for rotating the receptacle about the axis of said orifice.



Heavy Clay Products

Rolling power costs downward. ANON. *Brick and Clay Rec.*, **68** [2], 110–14 (1926).—A pictorial description of the new plant of the Fairfield Brick Co., Zoarville, O. By an efficient layout and by the use of ball and roller bearings throughout, the company hopes to show a power saving of 50%. The Minter system of drying and firing is used. R. E. G.

Modern tile making. A. B. SEARLE. *Brit. Clayworker*, **34**, 329–30 (1926).—S. describes a method for feeding open trough mixers and expression rolls. H. G. S.

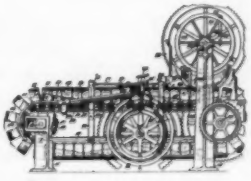
The history of English brickwork.—II. ANON. *Brit. Clayworker*, **34**, 331 (1926). H. G. S.

Darkening hand-made brick and tile. ANON. *Brit. Clayworker*, **34**, 338 (1926).—A method of flashing brick and tile with $MnCl_2$ is used in some cases to darken brick and tile. The $MnCl_2$, in powder or crys. form, is introduced at a time when the fires are clear of smoke and flame, and the goods are at full heat. The amt. depends upon the size of the kiln, and must be detd. by expt. and by the amt. of darkening required. It should, to the quantity of 20 to 25 lbs., be dropped on the top of the bricks in the down-draft kilns, the damper being nearly closed for 30 mins. Full firing can then be resumed with the damper up. The darkening will not extend to the whole mass of goods, but about half-way down, unless an excess of salt is employed. A similar method could probably be used in continuous kilns by distributing the salt in the many fire holes. H. G. S.

The first white brick plant in the South. C. E. WILLIAMS. *Manufacturers Rec.*, **89** [4], 56 (1926).—An illustrated account of the plant of the Georgia White Brick Co., Gordon, Ga. F. G. J.

Extensive development of heavy clay products in Alabama. E. A. SMITH. *Manufacturers Rec.*, **89** [4], 59 (1926).—The firebrick and vitrified paving brick industries are well developed. There is an enormous deposit of mat. classed by Dr. Ries as a flint clay. He gives the anal: SiO_2, 85.70; Al_2O_3, 6.15; Fe_2O_3, 1.80; CaO, trace; combined water 7.00. This should some day find a ceramic use. The value of ceram. products of the state increased 333% from 1903 to 1923. F. G. J.

PATENT



Shaping and trimming attachment for tile-forming machines. MAX MUELLER. U. S. 1,572,028. Feb. 9, 1926. A shaping and trimming attachment for tile forming machs., comprising a plurality of forming blocks mounted on an endless conveyor, a pressing mechanism in close proximity with the blocks, a trimming mechanism for trimming the bottom edges of the product, means for controlling the elevation of the trimming means, and a cutting off mechanism.

Refractories

Refractories for blast furnaces and coke ovens. M. C. Booze. *Blast. Fur. and Steel Plant*, **14** [2], 86–88(1926).—The more important causes for the failure of blast fur. linings are abrasion, fusion, soln., disintegration due to the deposition of carbon or the condensation of carbon in the pores of the brick, and reduction in refractoriness by reaction with alkalis which penetrate the lining in the form of vapor. Temperatures near the tuyeres have been detd. to be as high as 3300°F and blast. fur. operators meet this condition by the use of cooling plates. The presence of reducible iron in fireclay brick is very disastrous, and its bad effects may be overcome to some extent by firing the brick hard enough to produce silicates of iron. The life of a fur. lining can frequently be extended by a variation in operating conditions or fur. design. Steam-pressed checker brick give better thermal efficiency in checkers than hand-made brick. Silica brick are the standard for by-product coke ovens. Their manuf. has attained a high degree of efficiency. Among their desirable properties are their extreme rigidity at high temps., good refractoriness, lack of shrinkage, high thermal condy., and resist. to abrasion. H. G. F.

The importance of refractory tests. M. C. Booze. *Fuels and Fur.*, **4** [2], 175–78 (1926).—A rev. is given of the history of research on refrac. and the institutions which have carried on this research are named. The value of the formulation of suitable tests is emphasized. The tests for which frequent need is found are as follows: (1) chem. anal., (2) softening point, (3) spalling, (4) deformation under load, (5) slagging, (6) contraction. These tests are described in detail and it is emphasized that the results of such tests must be interpreted by one of broad experience. R. M. K.

Refractories for gas retorts, with special reference to silica. W. Emery. *Trans. Ceram. Soc.* (Eng.), **24** [4], 361–401(1924–25).—Discusses the advantages and disadvantages of gas retorts made from siliceous and highly siliceous mats. Data is given on a number of installations where silica retorts are in use, covering fuel, conditions of refracs., output per day, day's gas-making, and time of shut-downs. R. F. S.

Dust counting in the pottery industry with special reference to health considerations. E. L. Middleton. *Trans. Ceram. Soc.* (Eng.), **24** [4], 348–58(1924–25).—There are 2 classes of dust particles: those which can reach the alveolar spaces in the ultimate lung tissue; and those which are arrested in the upper air passages. The 1st class includes very fine particles, which are capable of remaining discrete, while the 2nd class comprises all the coarser dusts and those which readily form aggregates. The fine, discrete dust is by far the more important from the point of view of the effect on health, and of the fine dusts which occur in industry the most destructive is silica in the form of flint. There are 3 methods of estg. the amt. of dust in the atmosphere: colorimetric, gravimetric, and enumeration. Dr. Owens' app. for dust examn. depends for its action on the principle that when air which contains dust passes through a narrow orifice toward a glass surface, which faces the jet a short distance away, the dust will adhere to the glass and can be examd. microscopically. This result is brought about by causing a very fine ribbon-shaped jet of air to strike a microscope cover glass placed about 1 mm from a slot-shaped opening forming the jet. The air before entering the slot passes through a damping chamber, and the velocity in the jet is such that a fall of press. results, thus bringing about a condensation of moisture. The air is then deflected and the dust, being unable to turn the corner, strikes the cover glass, the velocity of the air falls off, the press. and temp. rise, causing the water to be evaporated, and the dust is left behind, which can be counted and examd. under the microscope. R. F. S.

Properties of sillimanite. Anon. *The Chemical Age*, **13**[338], 576(1925).—Discussion of properties of sillimanite with particular ref. to its use for making glass

pots. Glass pots made of 70% sillimanite and 30% ball clay gave satisfactory service as to resist. to temp. shock and corrosion by glass. E. E. P.

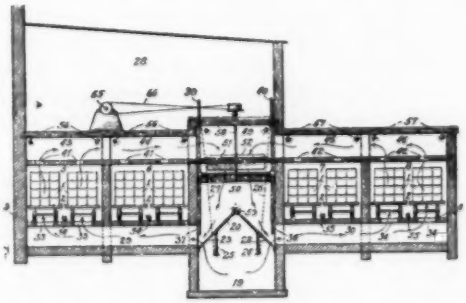
United States Master Specification for fire clay. ANON. Bur. of Stand., *Circ.*, **298.**—Fire clay is to be tested for the foll. properties: (*a*) fineness, (*b*) bonding power, (*c*) softening point, (*d*) simulated service test. Fineness is detd. by hand washing and sifting through a 20-mesh seive. For fine fire clay not more than 4% shall remain; for commercial, not more than 10%. Bonding power is tested by bldg. a pier of 3 bricks using the fire clay to make joints less than $\frac{1}{8}$-inch thick, and firing this to 300° lower than the min. allowable s. p. of the bricks to be used. After cooling in the fur. the pier shall be sufficiently well bonded to remain intact when lifted by grasping the top brick. The s. p. is to be detd. by the A. S. T. M. Standard Method C 24–20. In the simulated service test an oil-fired fur. is built up with one side of acceptable brick, the other of brick and clay under test. The test consists of 2 runs of 24 hours each at fur. temps. of 1590 and 1650°C respectively. A spalling test is conducted at the conclusion of each run by injecting cold air at high velocity into the fur. immediately after shutting off the oil supply to the burner. The injection continues until the walls are cool. F. G. J.

Powdered fuel and fire brick. ANON. *Brit. Clayworker*, **34,** 335 (1926).—There is a tendency to avoid powdered fuel firing because it is assumed that this method of firing is severely destructive to the brickwork. Modern practice has overcome this objection by (1) extremely fine pulverization (85% passing through a 200-mesh sieve), (2) drying the coal, (3) using a low air press., and (4) using large combustion chambers. The fuel should also have an ash of low m. p. and the fire brick should contain at least 34% Al_2O_3. H. G. S.

Fractional fusion of refractories. R. HUSTIN. *Chimie et ind.*, **14,** 691–92 (1925).—On changing the lining of a reheating furnace from ordinary grade of brick to a special grade, the life of the lining was increased from 1 week to 4 weeks. The special bricks fused partially during the first week, after which fusion stopped and the bricks gave good service. Anal. of the unaffected and of the fused portions of the bricks gave: SiO_2 78.80, 56.30, Al_2O_3 18.28, 31.53; Fe_2O_3 2.47, 8.97; CaO 0.56, 2.17; MgO 0.26, 0.62%, resp. The change in compn. is due to the loss of 51% (on the original wt. of the brick) of free SiO_2, which formed fusible silicates with fluxing agents introduced with the C. The resultant increase in the Al_2O_3 content of the outside of the brick increased its refractoriness, resulting in increased life of the lining. Similar reactions might occur in the absence of external fluxing agents by reaction of the free SiO_2 with the fluxing agents in the brick itself. (*C. A.*)

PATENTS

Method of alloying rare metals and articles made therefrom. WILLIAM BENJAMIN GERO. U. S. 1,566,793, Dec. 22, 1926. The steps in the method of prepg. a refrac. metal from a comminuted form which comprise coating the individual particles thereof with a volatile protective agent and sintering said particles into a coherent state.



Method of and apparatus for drying refractory materials. WILLIAM E. WILSON AND HENRY G. LYKKEN. U. S. 1,570,659, Jan. 26, 1926. A method of drying refrac. ware, comprising moving the ware through a htg. and humidifying medium, the ware being subjected to increasing temps. and decreasing humidities during said

movement of the ware through said medium, causing a general travel of said medium in a direction opposite to the travel of the ware, and forcing said medium at successive points vertically through said ware.

Batch for making ceramic material and a ceramic material made therefrom. FRED M. LOCKE AND FRED J. LOCKE. U. S. 1,572,730, Feb. 9, 1926. A raw batch for refrac. bodies contg. a relatively small amt. of a compd. of manganese and a relatively large amt. of clay.

Refractory cement and concrete. PAUL JEAN FREDERIC KESTNER. U.S. 1, 573, 072, Feb. 16, 1926. A compn. of matter constituting a refrac. cement, consisting of a mixt. of 1 to 10 parts of bauxite which has been calcined at a temp. above the point of transformation of alumina, and 2 parts of a calcium aluminate cement containing at least 30% of alumina, the said calcined bauxite and calcium aluminate cement being mixed in the form of powder.

Fire brick or block. RICHARD A. DALTAN. U. S. 1,573,482, Feb. 16, 1926. A fire brick or block including a body portion, said body portion comprising slag from a high temp. forced draft fur. which is free from ashes, a fire cement which sets hard at a high temp., Port. cement which sets hard at atmospheric temps., and a facing compn. comprising divided carborundum, a fire cement which sets hard at a high temp., and Port. cement which sets hard at atmospheric temp.

High-temperature cement. PAUL G. WILLETTS. U. S. 1,573,888, Feb. 23, 1926. A cement contg. barium sulphate, silica and silicate of soda.

Terra Cotta

The application and grinding of engobes. P. JÜRGEL. *Keram. Runds.*, **34,** 17–19 (1926).— By engobes are meant white or colored slips which are applied to leather hard bodies in order to conceal the more undesirable color of the body. Many natural clays are used for this purpose and they are usually ground on the old stone block mills. It is important that the engobe should have the same shrink. as the body. These are compared by molding the body and engobe into 80x30x7 mm pieces in plaster molds. Shrink. marks are placed diagonally across these pieces and the drying and firing shrinkages are measured. If these do not agree they are adjusted by adding more plastic lean mat. to the engobes as is required. If white engobes have a cream tinge, 0.01–0.02% CoO may be added. The addn. of ZnO to the slip may greatly whiten the color but is too expensive for ordinary work. The slip is usually applied by pouring it in a leather hard vessel and emptying out the excess. A common defect which may occur is pinholing. The most common source of this trouble comes from applying the slip to ware which is too dry. Dry ware is more or less porous and when the H_2O is absorbed by the ware gases are forced through the slip causing pinholes. Another source of pinholes arises from the fermentation of the engobe. This often originates from old wooden containers which have started to decay. Using new wooden containers will often remedy pinholing from this source. If dark clays are used in the engobe they often contain pyrites which may cause pinholing during firing since gases are given off of this mineral at high temps. Grinding the clay and hence the pyrites finer will tend to overcome this trouble. Typical compns. of some engobes are as follows:

	Meissen-H-Rühle (White)	Dölan (Halle) Gebr. Baeusch (White)	Washed Cadiner clay (Colored)	Helmstedter clay (Colored)
Al_2O_3	25.57	37.03	11.26	18.89
SiO_2	62.52	48.15	60.16	73.20
MgO	0.10	0.30	2.03	1.40
CaO	0.65	0.27	5.41	2.87

Fe_2O_3.....	0.92	0.60	6.84	4.27
K_2O.....	1.04	0.82	4.02	1.05
Ignition loss.....	9.27	12.76	10.21	6.33

To produce engobes of different colors, oxides may be added as follows: For brown Fe or Mn oxides; for blue, CoO; for green, Cu or Cr oxides; for yellow, small amts. of Fe_2O_3 or TiO_2; for black, a mixt. of Fe, Cr and Co oxides. About 2–6% of these oxides usually give the desired colors. Many effects may be produced by using two or more colored engobes. By splashing these upon each other many artistic speckled and marble effects may be produced. With the aid of parchment stencils many figures and designs may be applied to the ware. Glazes as a rule are applied over the engobes but if 30–50% of the glaze is added direct to the engobe matt finishes are produced which do not require a glaze. H. G. S.

White Wares

Machine for coating tiles with enamel glazes. CLIFTON REYNOLDS. *Trans. Ceram. Soc.* (Eng.), **24** [4], 325–28 (1924–25).—The mach. consists of a conveyor made up of rollers set at such a distance from each other that they will, when rotated in the same direction, carry forward from one to another, a board, along the upper surface of which tiles are placed. The tiles are held in close contact with each other by means of a spring and no glaze can fall between them. There is provided a glaze-feeding device capable of producing a perfectly even fan-like stream, the strength of which can be finely controlled. The bisque takes up all the glaze ever required for the stream falling evenly across the entire width of the tile will cover the tile in any required time by accelerating or retarding the speed at which the tile passes through it. Surplus glaze will fall over the outside edges of the tiles overlapping the boards and will be received in a suitable vessel underneath for return to that above. If it is desired to remove glaze from the edges of the tiles this is very simply done by knife edges impinging by adjustable springs on the edges of the tiles as they are propelled by the conveyor. The advantages are: accurate adjustment of the thickness of glaze on the tiles, even surface of glaze all over each tile, no skilled labor required, speed, and economy. R. F. S.

Notes on fritting. S. R. HIND. *Trans. Ceram. Soc.* (Eng.), **24** [4], 329–37 (1924–25).—This paper deals only with thermal efficiency of fritting and effect of fuel on design. A comparison as to cost is made for a coal fired frit-kiln and a U. S. rotary kiln. The U. S. rotary kiln is discussed as to its economic features and the quality of the product. R. F. S.

Porcelain for high tension insulators. K. H. REICHAU. *Trans. Ceram. Soc.* (Eng.), **24** [4], 279–99 (1924–25).—The porcelain insulator must ensure the absolute elec. and mech. reliability of the high tension line under normal service conditions. It must show the complete absence of porosity with a well-glazed and non-granular fracture. Bodies with a high content of feldspar cannot be employed for high tension insulators. Such short bodies cannot be easily worked in the green condition. Also, it is impossible to produce articles which are thick in places and thin in others because the thin portion of the insulator, such as the thin wall of a groove, begins to melt before the thick portion has been completely fired, and insulators of this type, owing to their high content of silica feldspar glass, are very sensitive to temp. changes. The porcelain should have the ability to withstand rapid, even though limited, changes of temp. It is also shown that a great many requirements, such as high mech. strength, both compressive and tensile, great elasticity and high dielec. strength are automatically fulfilled, and a further very important asset is obtained automatically—the absolute chem. stability of the mat. and immunity from aging. R. F. S.

Experiments covering the translucency of porcelain. R. RIEKE AND K. SAMSON. *Trans. Ger. Ceram. Soc.*, **6** [5], 189(1925).—As a general rule translucency increases with higher firing temp. Where the rational compn. varies it is found that the compd. contg. the most glassy mat. shows the highest translucency. Different varieties of kaolin and quartz give markedly diff. results. Translucency increases with finer grinding of the silicate constituents. Pegmatite shows varying results. Addition of slight quantities of whiting or magnesia increases translucency. Iron has the opposite effect. By first mixing and fusing the quartz and feldspar, a body of exceptional translucency is obtained.

F. A. W.

Preparation and constitution of German insulator bodies. ED. THIESS. *Ceram. Ind.*, **6** [2], 191–92(1926).—The German and Bohemian high tension porcelain consists, in the av., of the foll. mats.: 47–50% kaolin and white-firing clays; 30–25% feldspar (Sweden); and 23–25% quartz sand or rockquartz (Norway). These are the best possible materials. About 90% of the Ger. high tension insulator bodies are prepd. by grinding the body mats. in ball mills. Most factories age the clay for long periods of time before working. Most of the ware is fired to cone 14 or higher. Cheap and highly skilled labor makes much hand work possible.

R. E. G.

Nine kiln plant fires seven glost kilns a week. ANON. *Ceram. Ind.*, **6** [2], 186–87 (1926).—A description of the Southern Potteries Co. plant at Erwin, Tenn. R. E. G.

Equipment and Apparatus

Notes on grinding and crushing machinery. F. LANE. *Trans. Ceram. Soc.* (Eng.), **24** [4], 310–24(1924–25).—Reducing by breakers is effected by "press. and release" alternating machines acting on commercially dry mat. Breakers are of 3 types: the reciprocating, or jaw-breaker type, gyratory or conical breakers, revolving or disk breakers. In the reciprocating type, the mat. is broken between a fixed and moving jaw as the latter advances toward the former. The discharge of the broken mat. is effected on the succeeding retirement, this disposition of the jaws allowing a further feed of fresh mat. to be broken. The stand. machines of this class are the Blake crusher type. The jaw breaker is simple, reliable, and takes up little space but the product of the jaw breaker is irregular, especially when the mats. are of a flaky nature. The output is more regular in size when the machine is fed fully loaded, not choked or overloaded. The gyratory breaker gives a continuous discharge of a fairly uniform size of mat. cubical in shape. The breaking is performed by the gyratory of a conical head within a fixed inverted conical ring. Compared with the jaw breaker, the gyratory machines employ power more efficiently, are less liable to choke, deliver a more regular product, and are lighter in wt. for a given capacity. Edge runner mills consist of two heavy rollers revolving and traversing a circular path, on which the mat. is reduced. This path may be solid or perforated, and may be stationary or revolving, and is carried by an iron pan, circular in plan, with sides formed to retain the mat. being ground. The reducing action by crushing and shearing is continuous, a wider roller increasing the shearing action. The edge runner mill is used for wet grinding for medium fine products of a granular nature. Grinding rolls effect reduction by the shearing action of two disks, the diameters of which are detd. by the size of the fed mat., and the length by the output required. Grinding by roll mills should receive much greater application than has yet been the case in the prepn. of refracs.

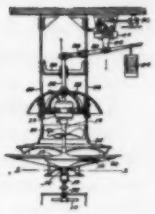
R. F. S.

High frequency-induction electric furnace for very high temperatures. G. RIBAUD. *J. Phys. Radium*, **11**, 295–99(1925); *Jour. Soc. Chem. Ind.*, **45B**, 64 (1926).—Describes R's graphite-porous carbon fur. Ten kw. give 3000°C for 100 cc fur., 2500° for 500 cc, and 1800° for 3 l. With 18 kw. and 5 l. vol., 2000°C was obtd.

H. H. S.

PATENT

Humidifier control. JOHN W. JACKSON. U. S. 1,572,432, Feb. 9, 1926. The combination of a humidifier having a supply of still water below, a fan above, and means between these for lifting water from said supply and discharging it into the blast created by said fan, with control means responsive to increase of humidity in the air adapted to move said water lifting means away from said water supply, thereby to stop the discharge of water into the air.



Kilns, Furnaces, Fuels, and Combustion

The efficiency of oil burners. W. TRINKS. *Fuels and Fur.*, **4** [2], 149–50(1926).—Purchasers of oil burners are warned that the efficiency rating of an oil burner as given by one test may not hold for any other test. The efficiency in a boiler test may be high but it does not always follow that similarly high efficiencies will be obtained if the same burner is put to different use. The efficiency of an oil burner in the usual sense of the term efficiency cannot be computed. The efficiency of an oil burner may be expressed in terms of its capacity to atomize oil very finely. An arrangement for making such a test of efficiency is described and the value of the information obtained in such a test is pointed out. R. M. K.

Relative value of carbon monoxide and hydrogen as constituents of producer gas. W. E. RICE. *Fuels and Fur.*, **4** [2], 151–62(1926.)—R. presents a rev. of some reasons advanced by a number of investigators for the fact that gases high in CO are of greater value as heating media in furnaces than other gases of equal calorific value but low in CO and high in hydrogen. The factors discussed are: (1) calorific value of gases, (2) radiation from flames, (3) flame temp., (4) rate of flame propagation of the flame and the limits of inflammability, (5) dilution by water vapor, (6) action of hydrogen flame on clay refractories. Many tables contg. valuable data are given to illustrate the discussion of the above subjects. The discussion brought out the fact that carbon monoxide possesses an advantage over hydrogen as a fur. fuel because of its higher net calorific value, the greater radiation from the flame and its higher flame temp. The methods of operating gas producers for the production of high carbon monoxide are given as follows: (1) The fuel surface exposed should be as large as possible. (2) The time of contact between the fuel and the gas should be made as high as possible. (3) The temp. should be maintained as high as practicable. R. M. K.

Electric kiln for firing porcelain. F. A. J. FITZGERALD. *Jour. Soc. Chem. Ind.*, **44,** 1250(1925).—The work done by F. and his associates is along the line of better refracs. and resistor elements. The elements are of carbon, and they are insulated from the interior of the kiln by carborundum. H. H. S.

New type tunnel kiln fires ware in cone 10 in 24 hours. ANON. *Ceram. Ind.*, **6** [2], 188–90(1926).—The article is an illustrated description of the plant and method of manuf. used by the Gem Clay Forming Co. of Sebring, O., which manuf. radiants and other types of refracs. for use in gas or elec. equipment. A new tunnel kiln fires the ware to cone 10 in 24 hours. R. E. G.

Keep your profits from going up in smoke. H. C. KENYON. *Brick and Clay Rec.*, **68** [2], 201–202(1926).—A description of the firing practice used by the Standard Brick and Supply Co., Charleston, W. Va., which was found to give a min. amt. of smoke. It was found that the amt. of smoke was dependent upon the manner of firing, rather than the type of fire box or kind of coal used, providing the stacks were of a sufficient height. The stacks used by the Company were 45 ft. high, which was 15 ft. higher than found necessary while firing with natural gas. During the water-smoking

period, the fire is kept in the rear of the fire boxes, against the bag walls. As the kiln heats up, the fire is increased until the fire box is full, after 48 hours. The method of firing is then changed to placing the green coal in the front of the fire box, only. R. E. G.

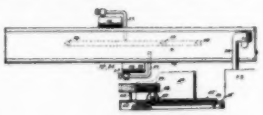
A new method of kiln firing. B. M. JOHNSON. *Ceram. Ind.*, **6** [2], 208–10 (1926).—J. stated that when using oil, instead of coal, the fire boxes should be redesigned. The carboradiant combustion chamber is described. This chamber consists of 2 rectangular flues, one superimposed upon the other, built up of relatively thin silicon-carbide tile. These flues are connected at one end. Oil is fired into the lower flue and the combustion gases return through the top flue and are permitted to escape into the kiln through openings. Tests made with this system of firing show: (1) easy control of heat, (2) a saving in fuel (19.3%), (3) easy control of atmos. conditions, and (4) simplifying construction and maintenance. It is thought that the control and perfect combustion will make possible open firings of many classes of ware now done in muffled kilns, *i. e.*, terra cotta and sanitary ware. R. E. G.

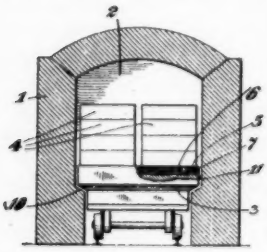
Heat insulation. ANON. *Brit. Clayworker*, **34**, 334–35 (1926).—The manuf. of clay-bonded kieselguhr insulating brick are described. The brick made in England may have as high as 20% clay and have a crushing strength of 64½ tons per sq. ft. H. G. S.

Some applications of electric heat in chemical industries. R. M. KEENEY. *Chem. Met. Eng.*, **32**, 922–25 (1925).—Describes the applications of elec. heat in the abrasive, automobile, baking, brass, enameling, chem., leather, metal working, paper, rubber, and steel industries. The author claims that with a power rate of 1 cent per kw. hrs. an elec. enameling fur. will have as low an operg. cost as a combustion fur. fired with 6 cent oil. M. E. M.

PATENTS

Continuous kiln. HALVER R. STRAIGHT. U. S. 1,572,327, Feb. 9, 1926. In a continuous kiln comprising a tunnel designed to receive a series of movable ware bearing cars, means for sealing the space between the cars and the walls of said tunnel so as to divide the tunnel into an upper and lower compartment at the floor line of the car, means for sealing the intake end of said kiln of both upper and lower compartments, means for sealing the outlet end of said lower compartment, a fur. between its ends, means for communicating the fur. with said upper compartment to receive the products of combustion therefrom, and means for communicating the fur. with the lower compartment of said kiln so as to supply the air for the initial combustion, and means for mechanically circulating air through the last conducting means.





Tunnel kiln. FRANCIS A. J. FITZGERALD. U. S. 1,573,543, Feb. 16, 1926. A sagger carrier for use in tunnel kilns consisting of a metal body the top of which is formed as a receptacle, divided refrac. heat-insulating mat. contained in said receptacle, and sagger-supporting members in said mat.

Geology

Georgia kaolins: Wilkinson County the center of production. R. T. STULL. *Ceramist*, **7** [4], 200–206 (1926).—The entire Ga. kaolin belt contains approx. 9,500 sq. m. or more than 20 times the area of Wilkinson Co., which is perhaps, the richest

county in potential mineral development. In Wilkinson Co., the minerals of commercial importance are kaolin, bauxite and fullers' earth. The estd. kaolin resources of Wilkinson Co. are sufficient to supply the ceram. and filler needs of the U. S. for over 600 yrs. at the present rate of consumption. There are 3 distinct types of kaolin: the flint variety, hard kaolin and soft kaolin. They are all very resistant to ht. and do not melt until temps. of from 3100°F to 3200°F are attained. The hard kaolins are used in the manuf. of refrac. and face brick; the soft kaolins, after washing, are used in the manuf. of pottery, etc., as an ingredient in ceram. colors, and as a filler for paper and oil cloth. Wilkinson Co. ships 70,000 T. of kaolin annually to the filler and ceramic trades. S. outlines the development of the ceram. indus. to date and the direction of future development. A. E. R. W.

The development of the ceramic industries in North Carolina. A. F. GREAVES-WALKER. *Ceramist*, **7** [4], 207–14 (1926).—Practically all of the country's supply of kaolin of the residual type and about half of the supply of orthoclase feldspar comes from N. Car.; until the middle of 1924, her other ceram. indus. were insignificant. At that time, a Ceram. Eng. Dept. was established at N. Car. State Coll. and a new era in the structural clay products indus. of the state began. G.-W. outlines the development of the ceram. indus. of the state since that time and predicts further development and expansion in the future. A. E. R. W.

Kaolin, feldspar, and pyrophyllite in North Carolina. JASPER L. STUCKEY. *Ceramist*, **7** [4], 215–22 (1926).—North Car. is the leading state in the South in the production of residual kaolin or china clay; it produces more feldspar than any state in the Union and has the only commercial deposits of pyrophyllite in the U. S. The value of these 3 mats. in the raw state, in 1924 was approximately $1,000,000. S. gives the mode of occurrence and distribution of the above minerals and discusses their commercial significance and possibilities. Pyrophyllite can be used as a substitute for talc and should find a wider use in the ceramic indus. and arts. A. E. R. W.

The high grade clays of South Carolina. F. H. H. CALHOUN. *Ceramist*, **7** [4], 224–31 (1926).—C. describes the geol. of the state in detail and then gives the occurrence and the extent of the clay deposits in the different geologic regions. The clays of the piedmont area consist of residual kaolins which are of value only in the manuf. of common brick and tile. The clays of the coastal plain area are essentially sedimentary in origin, their extent and mode of occurence are shown by means of a map and diagram. The fine white plastic kaolins are the most important and are found in 3 areas: one in the vicinity of Aiken, another in the vicinity of Seivern and Rayflin, and a 3rd near Harrell Hill, Richland County. The kaolin output of the state is used chiefly for filling purposes. The brick clays of the coastal plain area are alluvial in origin. The huge bldg. program throughout the South, and especially in Fla., has resulted in a great impetus for brick manuf. A. E. R. W.

Resources and ceramic industries of Tennessee. R. LEE COLLINS AND JOSEPH K. ROBERTS. *Ceramist*, **7** [4], 232–47 (1926).—C. and R. point out the many advantages Tenn. offers for the development of existing plants and the establishment of new branches in the ceram. indus. Tenn. leads in the production of ground feldspar and ball clay. The clays are mined chiefly in Henry and Carroll counties and most of the production goes to points outside the state. Most of the mining is done from open pits. The feldspar indus. is represented at present only by grinding mills, of which 4 have been in operation since 1922. The manuf. of chinaware, porcelain and similar high grade products is at present rather limited and confined largely to the eastern part of the state. Stoneware and pottery are manufd. at 3 plants in the state. Brick plants are scattered rather widely throughout the state, furnishing more than an adequate local supply. Overproduction of common brick has crowded the market to

some extent and rather keen competition exists among some of the larger mfg. centers. There are many plants mfg. brick from shale. A. E. R. W.

The commercial clays of Arkansas. GEORGE C. BRANNER. *Ceramist*, **7** [4], 250–53 (1926).—B. gives a concise description of the clay areas of Ark. illustg. his remarks by means of a geologic map of the state. A list of the plants in operation in the state and their prduction in 1924, is given and the advantages of Ark. in the matter of coal, fuel oil and natural gas are pointed out. A. E. R. W.

Clay resources of West Virginia. I. C. WHITE. *Ceramist*, **7** [4], 254–60 (1926).—West Va. possesses enormous quantities of the common minerals but practically none of the rare ones. Not the least of her mineral possessions are vast quantities of clays and shales from which a great variety of fired clay products can be manufd. Common clays, clay shales and pottery clays are produced in large quantities but the finer clays are imported. W. gives typical anal. of the various types of clays and shales and lists the indus. in which they are used. A. E. R. W.

Missouri clays. H. A. BUEHLER. *Ceramist*, **7** [4], 261–66 (1926).—The total output of the clay products indus. of Mo. in 1924 was valued at $20,000,000. The clay products indus. are the 2nd most important group of indus. in the state. The production of high grade fire brick is the outstanding clay indus. and was based originally on the use of the Cheltenham clay of the St. Louis district. The commercial deposits of diaspore clay which have been discovered during the last 6 yrs. have enabled the indus. to produce super-refrac. that are without equal in the market. B. gives the occurrences, properties and uses of Cheltenham clay, flint clay, diaspore clay, kaolin, china clay and shale. Refrac. and heavy clay products are the most important products. A. E. R. W.

Clays and shales of Oklahoma. CHARLES N. GOULD. *Ceramist*, **7** [4], 267–72 (1926).—Clays and shales suitable for a wide variety of uses are found in practically all parts of Okla. The most important ceramic products are bldg. brick and paving brick. Although there is an abundant supply of raw mats., no sewer tile or drain tile is manufd. in the state and only a limited amt. of bldg. tile. The great bulk of the clay and shale deposits of Okla. are included in the Pa. formations which occupy the eastern part of the state. G. outlines the important areas of mineral deposits in the state using a map for illustration. He points out the abundance of fuel and the probability of rapid development. A. E. R. W.

The clay working industries in Florida. HERMAN GUNTHER. *Ceramist*, **7** [4], 273–76 (1926).—Although the use of Fla. clay for the manuf. of common bldg. brick dates back to the very early settlement of the state, the development of the indus. has been slow because of the abundance of timber. The gradual depletion of the forests has created a demand for this type of product and there were 18 plants mfg. bldg. brick and tile in 1925. The Fla. clay of greatest commercial importance is the sedimentary kaolin found in peninsular Florida and mined in Putnam and Lake counties. Florida kaolin finds its chief uses in the whiteware indus. More recently it has been used as a filler in the rubber indus. and also, to some extent, as a paper filler. The majority of the raw clay is shipped out of the state but an increasing amt. will undoubtedly be used within the state for the manufacture of high grade pottery wares. The so-called common clays are found in all of the formations in Fla., the most important deposits being in Santa Rosa and Escambia counties. A. E. R. W.

The South's possibilities for glass and Portland cement industries. G. R. SHELTON. *Manufacturer's Rec.*, **89** [4], 55 (1926).—The 3 raw mats.—sand, limestone, and clay or shale—used in the glass and cement industries, are found in inexhaustible quantities in the South. Fuel, as coal, oil, and gas, is abundant. Plants are increasing in number but have not caught up with the local demand. A geol. account of the sand and limestone formation is given. F. G. J.

Abundant variety of clays in Arkansas, with gas, oil, and coal available. G. C. BRANNER. *Manufacturer's Rec.*, **89** [4], 58 (1926).—This account, by the state geologist, covers the subject in a thorough manner. Bauxites have been extensively developed but valuable primary kaolin deposits remain untouched. F. G. J.

The clays of Florida and their possibilities. HERMAN GUNTHER. *Manufacturer's Rec.*, **89** [4], 60 (1926).—In addition to the minor deposits of common clay for small local uses, Fla. has its famous deposits of sedimentary kaolin. This clay is washed from sand and mica and shipped all over the country. F. G. J.

Georgia rich in wide variety of mineral resources. A. V. HENRY. *Manufacturer's Rec.*, **89** [4], 61 (1926).—Approx. one-half of the white firing clay consumed in the country last year was mined in Ga. Bauxite is also mined on a large scale. A long list of other commercial minerals are noted. F. G. J.

The fire clays of northeastern Kentucky. Products now worth $5,000,000 annually. W. R. JILLSON. *Manufacturer's Rec.*,**89** [4], 62 (1926).—A description of the rapid growth of the Olive Hill district fireclay indus. F. G. J.

$12,000,000 annual output of clay products in Missouri. H. A. BUEHLER. *Manufacturers' Rec.*, **89** [4], 63 (1926).—The flint, plastic and diaspore clays of the state are the basis of a large indus. Brick, tile, and sewer pipe are also freely manufactured. Geological occurrences are described. F. G. J.

$5,000,000 annual production clay-using industries in Maryland. E. B. MATHEWS. *Manufacturer's Rec.*, **89** [4], 64 (1926).—The outstanding feature is the residual kaolin, famous for its whiteness. F. G. J.

Survey under way on clay resources of Louisiana. J. W. WHITTEMORE. *Manufacturer's Rec.*, **89** [4], 64 (1926). F. G. J.

Extensive deposits of clays in great variety found in Mississippi. E. N. LOWE. *Manufacturer's Rec.*, **89** [4], 65 (1926).—The deposits include sedimentary snow-white kaolins and ball clays. F. G. J.

Ceramic resources of North Carolina. Significance of department established at State Engineering College. A. F. GREAVES-WALKER. *Manufacturer's Rec.*, **89** [4], 65 (1926).—There is a large indus. in mining residual white firing kaolins and feldspars. Heavy clay products are well represented. A dept. of ceram. eng. was established in 1924 which offers correspondence courses as well as regular instruction. F. G. J.

75,000,000 brick produced annually in Oklahoma. Abundant supplies of shales, clays, and fuels. C. N. GOULD. *Manufacturer's Rec.*, **89** [4], 68 (1926).—An acct. of the resources and opportunities in Okla. F. G. J.

Increasing use of South Carolina clays as paper filler and for pottery ware. STEPHEN TABER. *Manufacturer's Rec.*, **89** [4], 69 (1926). F. G. J.

Tennessee leads in ball clay and ground feldspar production. R. L. COLLINS. *Manufacturer's Rec.*, **89** [4], 70 (1926). F. G. J.

$5,000,000 value of Texas clay products in 1924. E. H. SELLARDS. *Manufacturer's Rec.*, **89** [4], 71 (1926).—A geol. description of the clay deposits. Mfg. is confined to heavy clay products. F. G. J.

Vast quantities of shales and clays widely distributed in West Virginia. I. C. WHITE. *Manufacturer's Rec.*, **89** [4], 72 (1926).—Gives location of available fireclay and shale deposits. Fuels of all sorts are abundant. F. G. J.

Chemistry and Physics

Anomalous flocculation in colloidal clays and soils. F. HARDY. *Jour. Phys. Chem.*, **30** [2], 254–65 (1926).—Reference is made to Comber's theory ascribing the anomalous flocculation of colloidal clay by lime to chem. reaction between the emulsoid

mat. of the clay and lime. Hardy observed the flocculation of lateritic soils by lime. The physico-chem. features of the hydrous alumina, ferric oxide, silica, alumino-silicates, and ferro-silicates occurring in clays are discussed with a view to explaining the phenomena. E. E. P.

Action of silica on barium and magnesium sulphates. G. MARCHAL. *Compt. rend.*, **181,** 784–86 (1925); *Jour. Soc. Chem. Ind.*, **45B,** 51 (1926).—When htd. alone $BaSO_4$ begins to decompose at 1510°, but when mixed with the theoretical amt. of SiO_2, the decompn. begins at 1025° according to the reaction $BaSO_4+SiO_2=BaO$, SiO_2+SO_2+O. For $MgSO_4$, the corresponding temps. are 880° and 680° respectively. The heats of formation of the silicate from the oxide and SiO_2 are 14.7 cals. for Ba, and 8.5 cals. for Mg. H. H. S.

The constitutional changes occurring in clays on heating. RESEARCH STAFF (The General Electric Co.) *Trans. Ceram. Soc.* (Eng.), **24** [4], 402–406 (1924–25).—The data presented resulted from an attempt to follow by X-ray methods the 500 and 900° changes in kaolinite, and to obtain information upon the stable compds. formed in fired clay. The fact established by X-ray study of the constitutional changes in clay is, kaolinite completely breaks down at about 600°, forming a silicate which is stable to about 900°. This silicate is presumably $Al_2O_3.2SiO_2$. At the higher temps. mullite is formed; the X-ray patterns of natural sillimanite and of mullite, prepd. by htg. andalusite at 1550° for 5 hrs. are different. The pattern of the mullite agrees with those obtained from fired clay mats. The mineral formed in clays at about 1000° is mullite and not sillimanite; the formation of mullite occurs in all the clays examd. by htg. for 5 hrs. at 1050°. The temp. at which complete stability is reached, *i. e.*, the point at which there exists only transformed quartz and mullite in the fired clay, varies according to the nature of the clay. R. F. S.

Hydrogen-ion determination of soils. H. NIKLAS AND A. HOCK. *Landw. Vers.-Stat.*, **104,** 87–91, 93–102 (1925); *Jour. Soc. Chem. Ind.*, **44B,** 1002 (1925).—*p*H detd. colorimetrically by using the nitrophenols as indicators agrees with that found by using indicators of Clark and Lubs. Both methods agree with the electrometric meas. H. H. S.

Critical *p*H for formation of hardpan in acid clay soils. J. R. SKEEN. *Soil Sci.*, **20,** 307–311 (1925); *Jour. Soc. Chem. Ind.*, **45B,** 24 (1926).—*p*H in the neighborhood of natural hardpans ranged from 4.7 to 4.95. The hardpan was cemented by Fe and Al compds. Expts. with artificial soils showed that Fe $(OH)_3$ may be pptd. in kaolin, giving a hardpan analogous to that found in the field at *p*H 4.4–5.0. It is concluded that there is a critical *p*H for hardpan formn. in an acid dry soil. H. H. S.

Two unusual colloidal soils. C. F. SHAW. *Soil Sci.*, **20,** 419–23 (1925); *Jour. Soc. Chem. Ind.*, **45B,** 24 (1926.)—(1) A soil mat. from the dried bed of a lake in California contd. 134–540% of water undrained. The moisture equiv. was 348–380, and the loss on ig. 38–54%. The soil had a horny texture when dry, and consisted of unweathered mat., the inorg. matter being mainly SiO_2. (2) A subsoil from Hawaii contd. 375% water. It was formed by weathering of lavas under high rainfall and temp., and was of an elastic consistency. H. H. S.

The twilight zone of matter. ALEXANDER FINDLAY. *The Chemical Age*, Pt. I, **13** [326], 274–75 (1925). Pt. II, **13** [328], 328–29 (1925).—Text of address on the colloidal state of matter. Reference is made to its practical applications. E. E. P.

Equilibrium in colloid systems. O. K. RICE. *Jour. Phys. Chem.*, **30** [2], 189–204 (1926).—Application of the phase rule to colloid phenomena. Equilibrium can exist only if particles are of one size or a few definite sizes. Equilibrium principles are also considered to explain coagulation. E. E. P.

BOOKS

Plastische Massen. Die Erzeugung, Verarbeitung und Verwendung. H. BLUCHER. Leipzig: Hirzel. 291 pp. Price M. 8; bound M. 10. Reviewed in *Ind. Eng. Chem.*, **17,** 1296(1925). (*C. A.*)

Das Wasserglas, seine Eigenschaften und Verwendung. H. MAYER. Pt. 79. Sammlung Vieweg. Tagesfragen aus den Gebie en der Naturwissenschaften und der Technik. Braunschweig: F. Vieweg & Sohn Akt.-Ges. 52 pp. R. M. 2.50. (*C. A.*)

Catalogue of British Scientific Technical Books. Compiled by Comm. of the British Science Guild. London: A. F. DENNY, LTD. 489 pp. 12 s. 6 d. Reviewed in *Chemistry & Industry*, **44,** 934(1925). (*C. A.*)

PATENTS

Process of making a reflocculated product. GEORGE WILSON ACHESON. U. S. 1,563,713, Dec. 1, 1926. Process of making a reflocculated product, comprising subjecting a finely divided solid to successive deflocculation and reflocculation under attrition.

Process for making heavy basic carbonate of magnesium. BERTRAND B. GRUNWALD. U. S. 1,573,603, Feb. 16, 1926. The process of manuf. of heavy basic carbonate of magnesium, which consists in introducing carbon dioxide gas into a mixt. of calcined magnesite and water and utilizing the resulting heat of reaction in the formation of the desired phys. properties of the resulting product.

Process for making light basic carbonate of magnesium. BERTRAND B. GRUNWALD. U. S. 1,573,604, Feb. 16, 1926. The process of mfg. a light basic carbonate of magnesium, consisting of htg. a mixt. of heavy carbonate of magnesium and water under agitation to a temp. not exceeding 180°F, whereupon the carbonate of magnesium expands in vol., and then cooling the mixt. by adding cold water to prevent further expansion.

Process for producing light basic magnesium carbonate. RUSSELL B. CROWELL. U. S. 1,573,632, Feb. 16, 1926. In a process of producing light basic magnesium carbonate, the steps which comprise reacting carbon dioxide gas with magnesium oxide in an aqueous medium until the ratio of CO_2 to MgO lies between the limits of 0.8 to 0.9, and htg. the reacted mass to a temp. not exceeding 140°F.

General

The ceramic resources of Georgia. A. V. HENRY. *Ceramist*, **7** [4], 195–98(1926). —In the southeast (Atlantic Plain) section of Ga. are found deposits of sedimentary kaolin, bauxite, fullers' earth, limestone, and alluvial clays; in the north and northeast (Appalachian) region are found the cryst. minerals, marble, feldspar, quartz, asbestos, graphite, corundum and rutile; in northwest Ga. are shales, refrac. clay, bauxite, limestone, manganese, iron ore, ocher, umber, barites, and coal. Deposits of kaolin, bauxite, fullers' earth, limestone, marble and shale are being worked at the present time and the deposits of the other minerals show promise. A. E. R. W.

Equipment and management of modern ceramic plants in N. America. W. STEGER. *Trans. Ger. Ceram. Soc.*, **6** [5], 202(1924).—Describes modern plant layouts, machinery, humidity driers, tunnel kilns, lab. control and govt. standardization of shapes, as seen during a recent visit to this country. F. A. W.

Standardizing china clay. ANON. *The Chemical Age*, **13** [331], (Suppl.), 12(1925). —Need of standard specif. tests for china clay is emphasized. Fineness is of prime importance for most uses, and depends chiefly on the washing process. Mica and other gritty constituents are sepd. by passing the clay-water mixt. through terraced channels known as "micas." E. E. P.

The weathering of clays. ANON. *The Chemical Age*, **13** [340], (Suppl.), 13 (1925). —Discussion of weathering of clays as affected by phys., chem., and organic factors. E. E. P.

Canadian Meeting. ANON. *Canadian Eng.*, **50** [5], 190 (1926).—Report of proceedings, papers presented, and election of officers of Convention of Natl. Clay Products Assn. (Canadian) at Toronto, Jan. 26–27, 1926. E. E. P.

Fifty years' progress in the pottery and glass trades—I. ANON. *Pottery Gaz. and Glass Trade Rev.*, **51** [583], 101–103 (1926).—A beginning of a rev. of the last 50 yrs. in glass and pottery manuf. This article is to be continued. R. E. G.

Speed reducers, when they should be used and why. ANON. *Brick and Clay Rec.*, **68** [3], 209–10 (1926).—The article gives a very complete description of various types of speed reducers and suggestions for their application in the clay indus. Advantages of the enclosed speed reducer are: (1) conservation of space, (2) safer than open gears, (3) permits the use of high speed elec. motors, which have a better power factor, (4) a saving in max. demand charges upon power unit, (5) elimination of production delays due to belts breaking, etc., (6) positive drive with no lost power due to slippage or belt creeping, (7) long life, (8) requires no attention except renewing of oil at long intervals, (9) very low maintenance charges, (10) makes possible angle drives, (11) greater efficiency in power transmission, and (12) larger speed reductions possible. R. E. G.

Significance of the American Ceramic Society Meeting at Atlanta. M. L. BRITTAIN. *Manufacturer's Rec.*, **89** [4], 51 (1926).—Outlines the plan of the Meeting and shows the commercial importance to both sides of actual contact of visiting experts with the ceram. resources of Ga. F. G. J.

Abundant clay and fuel resources for development of a great ceramic industry South. ANON. *Manufacturer's Rec.*, **89** [4], 47 (1926).—A general article on the growing importance of the South as a field for the development of ceram. indus. Tables of the production in 1924 of clays, feldspar, and bauxite are given and the needs of the indus. are outlined. F. G. J.

Ceramic manufacture in Georgia—its economies and possibilities. J. M. MALLORY. *Manufacturer's Rec.*, **89** [4], 52 (1926).—As extensive and potential as is the Georgia kaolin belt, the reasons and hope for ceramic manuf. in this section do not depend on clay alone. All of the other necessary ceramic mats. are available close by. The price of labor is low. Prices are given for bldg. mats. and fuels. The barrier of lack of skilled labor has been exploded by other industries. Instances are cited. Freight rates are low to a large group of population. These economic advantages cannot be ignored. They have been recognized by the steel, cotton milling, and cement industries. Large companies are bldg. branch factories in the South. Georgia should be especially attractive to a refrac. industry. F. G. J.

Remarkable adaptability of southern labor to the ceramic industries. V. V. KELSEY. *Manufacturer's Rec.*, **89** [4], 54 (1926).—A rev. of labor conditions available for ceramic indus. in the south. F. G. J.

Pioneering in southern fired clay products. B. MIFFLIN HOOD. *Manufacturer's Rec.*, **89** [4], 49 (1926).—A story of the development of ceramic plants in the South. A study of the reasons for fired clay roofs in many parts of Europe led to the establishment of 4 roofing tile plants at southern points. The story is told of the steps that led to the creation of the school of ceram. eng. at Ga. School of Tech. and of the promotion work of the Central of Ga. Ry. The development of the Georgia White Brick Co. is described and the opportunities awaiting development in other lines are pointed out. F. G. J.

Advantages of lime in water softening. C. P. HOOVER. 7th Ann. Convention, Natl. Lime Assn., Tech. papers and addresses, p. 70, May, 1925.—Municipal water softening plants are increasing rapidly and use lime because: it softens the water by the cheapest method; it kills bacteria; the water is clarified; coloring agents are removed; it removes carbonic acid; it sterilizes the water; it really adds nothing to the water. F. G. J.

Big savings from water softening. CHAS. A. MILLAR. *Manuf. in Canada*, **1** [1], 30(1926).—The Ontario Sewer Pipe and Clay Products, Ltd., Mimico, Ont., reports considerable saving in their boiler room as the result of installing a water softening plant. E. J. V.

News of ceram. industry. ANON. *Manuf. in Canada*, **1** [1], **40**(1926).—One brick plant has been registered, another incorporated, and a pottery has been established. E. J. V.

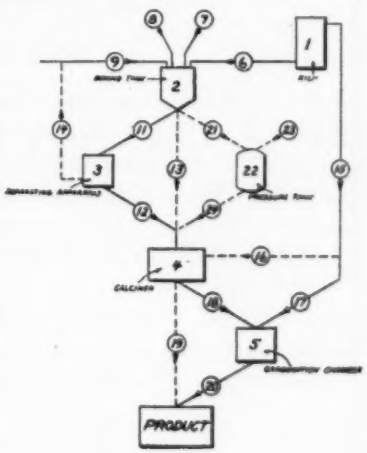
Steam generation in 1925. D. BROWNLIE. *Jour. Soc. Chem. Ind.*, **45**, 21–22 (1926).—The stage has been reached of the almost completely automatic boiler plant with pulverized fuel, steam meter mechanism controlling the supply of air, pulverized fuel, and feed-water. A continuous running efficiency of 90% all the year round is now almost certain, with 94–95% for short trials of 24 hrs. The types of app. mentioned are: the Murray water-cooled fin-tube fur. wall, the Broido boiler, the Becker flash boiler, the Austrian Loffler high-press. system, the Atmos revolving tube boiler of Blomquist in Sweden, the Benson tube generator, the Brunler boiler, and the McEwen-Runge process for low-temp. carbonization in conjunction with water-tube boiler. H. H. S.

Lead-poisoning. ANON. *Jour. Soc. Chem. Ind.*, **44**, 1254(1925).—Since the new regulations came into force last March 1, only 15 cases have been reported among pasters engaged in the manuf. or repair of elec. accumulators. There were 42 cases in 1924, and 44 in 1923. H. H. S.

The organization of scientific research throughout the [British] Empire. T. H. HOLLAND. *Jour. Roy. Soc. Arts*, **74**, 3–27(1925). (*C. A.*)

PATENT

Article of manufacture and process of making same. HERBERT A. ENDRES. U. S. 1,574,380, Feb. 23, 1926. The process of producing a finely divided mat. comprising htg. a mixt. of a finely divided silica and lime in water, and then calcining the resulting product.



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A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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EDITORIALS

MACON'S REACTION

Macon entertained, got acquainted, and now wants to have a more intimate relation with the ceramists who convened in Georgia during the week of February 8. Macon voted overwhelmingly to exempt new industries from taxation for a period of five years. Only twenty-two voters were against the measure. Columbus, Augusta, and other clay centers are mulling over similar plans for attracting manufacturing plants. With the rapidly increasing local market; with excellent rail facilities to inland and coast gateways; with the modern power developments and water availabilities; and with the moderate climate and cheap labor Georgians should not find it difficult to put across the economic advantages of manufacturing in Georgia.

But of equal if not of more importance is a demonstration by laboratory developments and by plant proving that in Georgia there are vast quantities of available raw materials. Georgia, North Carolina, and Louisiana have set up ceramic laboratories in their State Universities, and Central of Georgia Railway is continuing surveys and investigations of southern ceramic materials. Investment of money and energy in making such agencies and procedures most productive of proved plant availability data on their raw materials is absolutely as essential as the obtaining and making known of favorable economic

conditions. The railroads and public utilities which do not invest in this sort of informing surveys and investigations are shirking their share of the burden and are delaying the day when the South will have ceramic factories equal to its resources and market.

FEDERAL BUREAU CERAMIC RESEARCH

On March 4th on call issued by J. W. Drake, Assistant Secretary of Commerce, representatives of ceramic trade groups gathered at the Bureau of Standards to consider:

1. The creation of a Permanent Conference on Ceramics and the Allied Industries, advisory to the Department of Commerce, which will properly represent all of the important industries within the field.

2. The formation of a smaller group, under the chairmanship of A. V. Bleininger, to act as an executive committee of the Permanent Conference.

George K. Burgess, director of the Bureau, announced the Bureau organization which would be in full consummation next July. He then asked the delegates present to organize a permanent conference board and an advisory executive committee. This was done as requested.

P. H. Bates will be in charge of all ceramic work at the Bureau of Standards and A. V. Bleininger will be chairman of the advisory committee.

To all honest efforts toward effective research in ceramics this SOCIETY will give every support. Its committees and officers will fall into line wholeheartedly with the plans of the Bureau of Standards, details of which have been reported by the current ceramic press. In addition this SOCIETY will continue its efforts to obtain a more substantial and more effective technical research organization of ceramic manufacturers.

That the scheme set forth by the Bureau of Standards is a shadow, true in outline, of the organization scheme proposed by the SOCIETY in May, 1925, is evident but that it is only a shadow is also evident. The scheme as adopted leaves the manufacturers impotent and wholly at the mercy of the judgment of the Bureau in the planning and executing of ceramic investigation. The manner in which and the degree to which the present set-up was dictated is typical of what will be continued.

It cannot be expected that either Mr. Bleininger or, through him as chairman, the individual members of his committee will be able to give that continuity of thought which is so essential to success to coordination in technical research. The formation of this committee is a distinct step in the right direction but is it only a step. What the ceramic manufacturers need is a chairman who will give his full time o planning and coördinating the scientific and technical investiga-

tions by and for the manufacturers. Rather than Bureau men taking the lead in this planning for the manufacturer, the manufacturers should take the helm.

It is neither legal nor workable for the manufacturers and Bureau to jointly employ a person to serve as research director for the Bureau and chief adviser for the manufacturers.

The character of work done and the interpretation of results obtained by the Bureau rest with the chief of the Division. Ceramics has been grouped with cement and a cement technologist placed in charge. There can be no question of the ability to organize and direct, nor of the honesty in intentions of Mr. Bates to perform and interpret, but it would be expecting something beyond human limitations for anyone other than a ceramist to serve satisfactorily as director and interpreter of ceramic research.

We continue our urging that ceramic manufacturers, through their respective trade associations so organize and employ a full time chief research adviser. The plan recommended in the May, 1925, editorial in this *Bulletin* had working strength and vitality whereas the scheme dictated at the conference on March 4 at the Bureau of Standards is only a shadow without effectiveness, resembling the plan proposed by this SOCIETY only in outline.

PAPERS AND DISCUSSIONS

OBSERVATIONS ON THE DEVELOPMENT AND USE OF STEEL DRYING EQUIPMENT IN THE CERAMIC INDUSTRY[1]

By H M. Schaab

The following observations are made in regard to a matter of great importance to the ceramic industry. Progress in efficiency and advancement in design of new types of equipment are the results of careful experimentation and hearty coöperation of a number of the members of the Society. Much progress has been made which could not otherwise have been obtained.

With the rapid depletion of our timber resources and the declining quality of wood suitable for drying boards and shods, it was necessary to look around for a satisfactory substitute. If the results which have already been obtained and the tests going forward at present continue to show favorable results, it will be apparent that not only has a satisfactory substitute for wood been obtained, but a material has been brought into use which opens up possibilities for economies in operation, expenses and superior quality of product that were never dreamed of before.

A great deal of progress has been made against prejudice to a new material, to a higher first cost, and to a departure from old accepted standards. Everyone realizes that the first cost should not necessarily govern the decision on the type of equipment to be installed. It should, rather, be the ultimate cost figuring in and recognizing the factor of reduction in operating costs on the product. Very little information is available as to the cost of operating wooden boards and shods and for that reason the difference in first cost looks like a mountain whereas actually is only a mole hill. Reduction in the cost of maintenance of better boards, reduction in insurance rate due to elimination of fire hazard, reduction of cost of reconditioning warped ware, and elimination of back charges on defective ware may, all taken together, more than offset any difference in first cost in a very short time.

In turning away from wood for use in drying boards and shods, we are getting away from a material which has been relatively low in price. It is therefore necessary to adopt the lowest priced suitable metal, which, as you all know, is steel.

There are quite a number of inherent advantages in the use of steel over wood. Steel is equally strong in all directions and therefore any shape may be given to the steel: rectangular, circular, cubical or spherical. Steel will not warp under ordinary conditions except by

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (Terra Cotta Division). Received January 6, 1926.

abuse. Connections between various components of steel boards may be made everlasting and rigid by welding, a result which is not obtainable with wood. Steel presents a smooth surface which permits the clay to slide easily and therefore shrink without cracking. Steel is a conductor of heat, whereas wood is an insulator. Steel lends itself to an infinite variety of designs, which makes it possible to fabricate almost any type of equipment desired.

FIG. 1.—Curled edge, curled corners, brick pallet. Bottom view.

With these features in mind, it has been possible for the steel fabricators to attain the following desirable results: (1) a very material reduction in the percentage of spoiled ware; (2) a lessened expense for reconditioning warped ware; (3) a considerably reduced drying time, and (4) a marked increase in quantity of ware that may be handled in a given space.

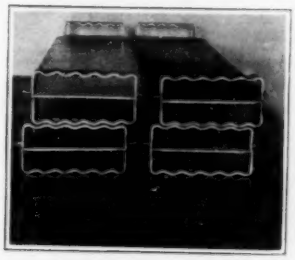

FIG. 2.—Double-reversible brick pallets stacked. End view showing how feet nest together.

Probably the main reason why steel has not heretofore been seriously considered by the ceramic industry as a whole is the inbred aversion of the clay worker to iron oxide.

However, there is a large field for the use of steel in that portion of the industry where the action of the metal is not injurious, namely in the manufacture of architectural terra cotta, sewer tile, conduit, grinding wheels and brick. Improved methods of protecting steel with metals which do not corrode, make steel available for use in the pottery industries making china ware, sanitary ware, porcelain insulators, etc.

The question may be asked just how it was found possible to use a steel board in the ceramic industry.

FIG. 3.—Terra cotta drying board. Terra cotta type.

Pressed steel pallets had been previously developed to replace those made of wood and cast iron in the manufacture of cement brick, cement block, concrete tile, and in the silica fire brick industries. It was but a logical step, therefore, to the drying of other articles, such as sewer tile, terra cotta block, grinding wheels, etc.

The first portion of the ceramic industry to realize that their difficulties with wood could be largely overcome by steel was the terra cotta plant. Quite a number of costly experiments were made with the aid of several well-known people in that industry, and as a result, a steel board has been perfected which has proved 100% in performance of its duty.

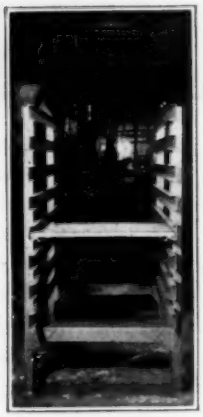

FIG. 4.—Drying racks for terra cotta. End view showing board in rack.

A board has been produced which remains flat, whether hot or cold, wet or dry, yet provides a large percentage of openings to allow air circulation to the back of the hollow blocks. It is practically indestructible. The supporting surface is flat at all times and is smooth, which allows the ware to creep uniformly, when shrinking. The steel conducts heat to the back of the blocks as well as letting hot air through, therefore promoting more uniform drying conditions.

The manufacture of this steel board is so flexible that it may be produced to meet the requirements of each individual plant, and work in with any system of handling, such as floor drying, rack drying or self-racking.

FIG. 5.—Sewer tile shod.

We might mention that a similar board has been designed and is being adopted by sanitary ware manufacturers.

The advantages of the steel boards are very real and vital to the terra cotta, but the advantages of steel are much more important to the sewer pipe and conduit industry, owing to peculiar conditions of drying. In this industry, it is common for the heated air to ascend from the basement through slatted floors on which the ware is placed to be dried.

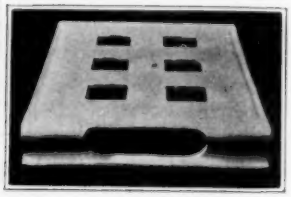

FIG. 6.—Conduit board. Six ducts.

Wood boards, of necessity, were made rectangular in shape and when placed edge to edge practically cut off the vertical flow of air through the slat. When steel was proposed it was immediately apparent that a circular shape was desirable which would allow, no matter how close together the boards were placed, a vertical stream of air to pass over the outside of the crock. By cutting out the center of the steel, a corresponding vertical flow of air is allowed to pass through the inside of the crock,

thereby making for uniform drying condition on the outside and inside, and the top and bottom.

Tests have shown that this feature alone reduces the drying time as much as one-third. The smooth surface of the steel permits the clay to creep easily and therefore cracked ware is practically eliminated. This is especialy true in the larger diameters, where the total shrinkage is correspondingly great.

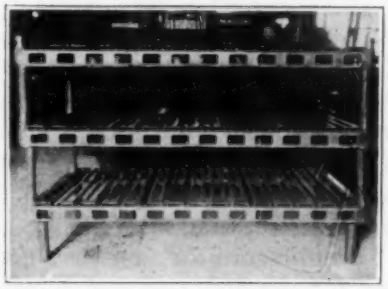

FIG. 7.—Conduit drying racks.

Due to the large flow of air past the drying surfaces, it is now possible to produce a three-foot length of pipe in large diameters, which has heretofore not been feasible, owing to a large percentage of defective material produced. The circular shape, the manufacture of which is possible only through the use of a metal such as steel, permits, by staggering, a large increase in the amount of ware which may be placed on a floor.

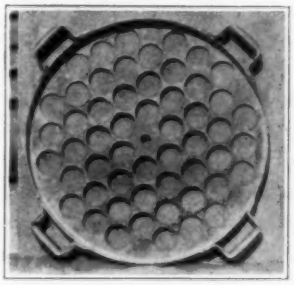

FIG. 8.—Round bat filled with plaster for drying grinding wheels, etc. Four handles.

While no new plants have yet been designed for the exclusive use of the steel shod, it is possible that the use of the circular steel shod in connection with certain advanced types of trucks and especially designed steel racks will make a very marked decrease in the cost of the building required.

For those plants that make conduit, a steel board has been developed, which, while rectangular in shape, produces the same results as for the sewer pipe. These are accomplished in a similar manner, namely, by providing a maximum of interior ventilation.

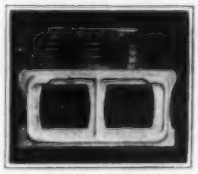

FIG. 9.—Rectangular bat for drying grinding wheels, etc. End view.

For the china ware, porcelain and grinding wheel industries, a steel bat holder has been provided, which materially reduces the thickness of plaster of Paris required, the result being that drying is considerably expedited and that the life of the bats is greatly increased.

Special types of coated ware boards and sagger boards are being produced for use in the pottery industries. Special shapes of pallets

and mold holders are now being tried out in the porcelain insulator factories.

In all of the industries a properly designed and manufactured steel board has been found to result in considerably lower operating costs, due to increased production of first grade ware and decreased loss of ware in its manufacture. Steel shods eliminate the fire hazard and thereby reduce insurance rates. Steel equipment can be designed in most cases to work along with wood, so that the replacement expense may be distributed over a period of time, although it would be a paying proposition to make a complete change-over and thus realize the total advantages accruing from the use of steel.

To disregard the first cost in the light of lower operating costs is a matter of sound, progressive business policy.

The Commercial Shearing and Stamping Co.,
Youngstown, Ohio.

SERVICE REQUIREMENTS FOR PLASTIC REFRACTORIES[1]

By Hugh E. Weightman

Introduction

Plastic refractories first appeared on the market as plastic fire brick Since that time many such materials have appeared, some better and some not fit for use. There has been much of the "follow the leader" type of production in these materials with the result that few, if any, of such materials are as good as they might be. If the plastics are to be the best possible in service quality, more coöperation must be given the manufacturer by the user.

When a setting is made with fire brick the greater part of the structure has been pre-fired to a high temperature, not more than 3 to 15% consisting of unfired mortar. With plastic refractories the entire structure consists of wet material with a grog or fired portion of only 25 to 50%.

Service Requirements

Heat can only be applied to one side of a plastic refractory wall. This makes the maturing of such walls very difficult. To overcome the danger incident to one side firing, the grog content of the plastic refractory has been increased to the maximum. Conduction of heat through the wall is needed to lessen the temperature differences, since such temperature differentials tend to stimulate shattering of the refractory. A certain amount of porosity is needed to insure a rapid dewatering of the mass. Firing control is hard to accomplish in the case of boiler

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (Refractories Division). Recd. Dec. 31, 1925.

furnaces and similar updraft furnaces, and as a consequence not much dependence can be placed in the ability to fire the average plastic refractory structure carefully.

Often barely enough heat is released in small furnaces to raise the temperature to a suitable point for maturing fire brick. Convection of heat from the outer walls causes a rapid decrease in temperature from the fire side to the outside. Under such conditions only a thin skin on the fire side has been matured. If the plastic has been well made for such service, the outer portion has "air set." Often some portion between the low temperature outer portion and the fire side of the refractory will have lost its air set quality and not gained a fire set. In such cases the refractory is fragile, dusty, and easily damaged.

While permeability to gases is desirable as allowing safer maturing of the structure, some furnaces make corrosive gases that attack the refractory. Porosity is desirable for rapid dewatering, but on the other hand it permits the walls to become an easy prey to adhering dust and slag.

Salty compounds in coal and oil, and iron dust in coal exert a rapid fluxing action on refractories containing free silica and especially in refractories containing sodium silicates.

In good average construction with plastic refractories, wall heights do not go over six feet. With properly buck-stayed walls the outer wall will not throw a load on the plastic wall. In some cases where the plastic linings have been added to old installations without repairing the outer walls the latter throw some load on the plastic. The load appears after the furnace has been in service. If the refractory is of sufficient mechanical strength and well matured not much harm in the average case will be done. Often the plastic either lacks strength to resist the load or is improperly matured.

Working floors or hearths in industrial furnaces are easily and reliably constructed of plastic refractories if care is taken to avoid buckling by expansion. The drawing of materials over such floors causes excessive wear unless the texture is made right by careful grading of the grog.

In the construction of deflecting pieces, arches and similar parts, plastic refractories are very convenient. Mechanical strength is the principal requirement for this service. Additional strength can be obtained in such structures by iron reinforcement. To insure a good bond between the iron and plastic, and to eliminate rupture due to expansion differences, the iron supports may be given a coating of sodium silicate and clay in a thin slip. The addition of some iron compounds to the slip helps. In such reinforcements care must be taken to allow for the growth of the metal.

Plastic refractories bear the same relation as fire brick in their limitations in metallurgical work. We cannot use the most refractory materials where oxides of the metals are produced, especially oxides of antimony, bismuth and zinc.

Deficiencies in Plastic Refractories

Strength The outstanding deficiency in plastic refractories is that of mechanical strength. When these are installed the material is pounded into forms with a mallet. The strength of the wall depends on how well this pounding is done. To simulate practice the plastic should be pounded into the molds. If this is done the breaking strength of the average samples on the present market will be from 50 to 100% higher than shown by Geller and Pendergast.[1]

The dry strength of some materials tests as high as 500 pounds per square inch. These materials were made of well-graded grog and considerable plastic clay.

Sizing of Materials Many plastic refractories are made of poorly graded materials. Occasional large pieces of ganister exert a tremendous pressure, spalling the refractory. The screen sizes used in the manufacture of plastic refractories should be such that the sample can be easily built into thin sections. Finer and more uniformly graded material will greatly improve the forming of plastic refractories and give greater mechanical strength.

Price Price is one factor that has retarded the more general use of plastic refractories. There appears to be no reason why such fancy prices should be asked for these materials. Some plastic refractories sell at $24 to $60 a ton and a few fancy ones at as much as $160 a ton. Even considering warehousing and extensive sales work, these prices are far out of line when it is considered that fired shapes of equal and better quality may be purchased for $20 a ton and less.

In spite of these exorbitant prices, plastic refractories are increasing in use on account of the ease with which they may be handled, and the ever-increasing cost of the furnace brick layers. Few, if any, plastic furnace linings exceed the life of a good fire brick installation, though often the operating labor can make a better plastic installation than to lay a firebrick setting. A reduction in the price to a more equitable level will greatly increase the use of plastic refractories.

Conclusion

The following requirements can be made in plastic refractories to meet service requirements:

[1] "The Laboratory Testing of Refractories," *Jour. Amer. Ceram. Soc.*, **8** [7], 441–51 (1925).

1. Increase the mechanical strength by better grading of grog and the use of plastic clay of greater binding power.

2. Elimination of an excess of ganister and soluble silicates. Where soluble silicates are used to increase the binding power, it should be indicated on the container.

3. When molded and fired the fracture of a sample of plastic refractory should present a flinty structure without large nodules. Sandy and rounded off particles should be avoided.

4. The body should not vitrify to a glassy structure to more than one-eighth inch. Closing of the surface pores is desirable to reduce slag and dust penetration and to prevent excessive clinging of ash to the wall.

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A FOUR-POINT MIXING DIAGRAM[1]

By K. M. Smith and W. L. Sample

Having considerable glaze development to do, the need was felt for a method of mixing glazes using four variables. The current literature yielding nothing, a method was evolved. Prior to the description of the four-point diagram, we shall take the liberty to review the triaxial diagram, with its three variables.

The triaxial diagram is a means of obtaining a multiplicity of glazes, (or other compounds) with the use of only three; in other words, in the pursuit of a glaze, instead of mixing and grinding batch after batch of glaze, three only are made, and mixed together in various proportions to produce an unlimited quantity of glazes, each one different from the rest. The saving of time and labor is obvious.

The triaxial diagram consists of an equilateral triangle having the sides divided into equal parts, the number being optional. The smaller the division, the more mixtures there will be. The divisions are then connected by straight lines, the connected lines being parallel to the unconnected side.

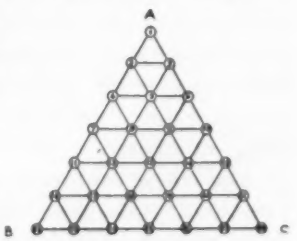

Fig. 1.

Figure 1 shows a diagram having the sides divided into six parts. This gives a total of 28 intersections, which correspond to the total number of glazes that will result from the

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb. 1926. (White Wares Division). Received Dec. 28, 1925.

Editor: The authors recognize that this is not new, yet it is not generally known.

mixing. Point 1, 22, 28, represent the three glazes A, B, and C respectively. All other points contain parts of two or all the glazes. To determine the amount of each glaze in each point, count the spaces between the point and the side of the triangle away from the glaze. For example: point 8 in Figure 1. Counting away from "A," that is, toward the base, from point 8 there are 3 spaces, representing 3 parts of glaze "A"; from point 8 to the side A–B, away from "C," there is one space, representing one part of glaze "C"; from 8 to the side A–C there are two spaces, representing two parts of the glaze "B." Tabulating, point 8 is made up of

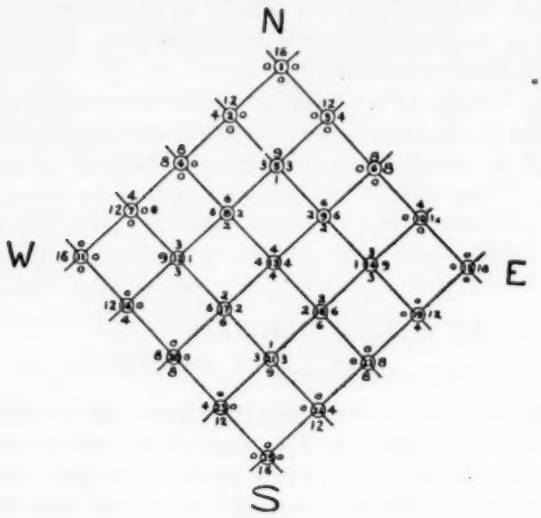

FIG. 2.

Glaze A	3 parts
Glaze B	2 parts
Glaze C	1 part
Total	6 parts

The total parts will always coincide with the divisions in the side of the triangle. The glazes in the sides will contain none of the glaze in the corner formed by the other two sides.

The Four-Point Diagram

The four-point diagram is essentially a square subdivided into smaller squares, and like the triaxial, the number of subdivisions is optional. Figure 2 shows a square divided into 16 small squares. It is made of ten straight lines, forming 25 intersections, corresponding to the total number of mixtures formed. In the diagram, the intersections have been numbered from 1 to 25, and around these numbers will be found four other numbers, representing the parts of each of the four glazes that go to make up the series. The four corner points represent the four glazes "N," "W," "S," and "E." The rule for computing the number of parts in each point is rather hard to give, and harder to understand; an example will be far simpler, so we shall sacrifice form for simplicity.

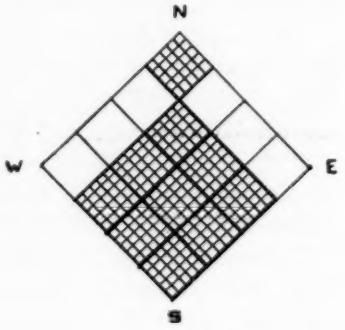

FIG. 3.

Let us take point 5, Figure 2. How much of glaze "N" in this? Count the squares enclosed in the angle to the south of the point. There are 9. This represents 9 parts of glaze "N," and corresponds to the number north of the point. Figure 3 shows this more clearly, the nine squares being shaded. Similarly, there is one square north of point 5, meaning one part of glaze "S." There are three squares East and West of the point, representing three parts each of "W" and "E." Having visualized this with the aid of Figure 3, we can state the rule in brief—count the squares in the angle opposite the angle containing the glaze.

The rule holds good for any size diagram, obviously enough. The writers have used this diagram in mixing colored glazes with very gratifying results. Using three colored glazes, and one uncolored, some rather pleasing tints have been developed, taking the series as a whole.

CAMBRIDGE SANITARY MFG. CO.
CAMBRIDGE, OHIO

DISCUSSION OF "THE THERMAL EXPANSION OF REFRACTORIES"[1]

M. C. BOOZE:[2] The data on thermal expansion of refractories given in this paper add to our knowledge since, as the author states, previous determinations of this property have rarely been made at temperatures above 1000°C. A number of conclusions are drawn, however, which warrant discussion. In some cases these conclusions are not supported by sufficient evidence to make them have as general application as is implied and in others there appears to be disagreement with known facts.

In the introduction the author states that "the tendency of a brick to spall, other things being equal, is proportional to the coefficient of linear expansion." The "other things" to which reference is made are diffusivity and elasticity or shearing strain. These latter factors are of first importance, as the author himself in a previously published paper[3] has shown, although he appears to have lost sight of that fact and leaves the impression in the paper under discussion that the spalling tendencies may be judged on the basis of coefficient of expansion alone. This impression is gained by such statements as "the materials most resistant to spalling are zircon, silicon carbide and kaolin . . . .;" "the different materials are listed . . . . to bring

[1] F. H. Norton, *Jour. Amer. Ceram. Soc.*, **8** [12], 826–28 (1925). Discussion received Feb. 10, 1926.

[2] Senior Fellow, Refractories Fellowship, Mellon Institute of Industrial Research, Pittsburgh, Pa.

[3] "A General Theory of Spalling," *Jour. Amer. Ceram. Soc.*, **8** [1], 29–39 (1925).

out their spalling resistance," and "in Table III the various specimens are listed in the order of excellence." In all of these cases the order of excellence is determined entirely by the coefficient of expansion values obtained by the author.

In the paper, "A General Theory of Spalling," by Mr. Norton, that has been referred to, he develops a formula showing the relation between spalling and the three properties, diffusivity, coefficient of expansion and (maximum) shearing strain. He then proceeds to measure these properties on various refractory brick and finds a relation between the values obtained by substitution in his formula and the results of spalling tests. This formula is simply

$$\frac{\text{coefficient of expansion}}{\sqrt{\text{diffusivity}} \times \text{(maximum) shearing strain}}$$

which in itself is ample evidence to show that spalling cannot be judged on the basis of coefficient of expansion alone.

In the data given in the earlier paper, one fireclay brick having a coefficient of expansion of .0000051 at 500°C withstands 26.5 quenchings, while another with very similar expansion (.0000053) withstands only 15.6 quenchings. Hard fired kaolin brick with a coefficient of expansion of .0000063 are shown as being only fair in resistance to spalling, since they fail in 10.6 quenchings. On the other hand, fireclay brick with a very high coefficient of expansion (.0000104) are somewhat more resistant to spalling, failing only after 12.2 quenchings. These appear as discrepancies only under the assumption that the coefficient of expansion is the dominant factor. The author himself shows that they are not discrepancies, explaining them by differences in the other properties named.

In the article under discussion, results are given on a variety of refractory products and there is no reason to believe that these products are alike in diffusivity and shearing strain. In fact, it is practically certain that they are very much unlike. In a paper by the writer and S. M. Phelps[1] it has been shown that the degree of firing affects the spalling tendencies to a marked extent, but may not have a pronounced effect upon the coefficient of expansion. The same was found to be true of the fineness of grind.

If our assumption that the samples tested by Norton are dissimilar in diffusivity and shearing strain is correct (and there can be little basis for contesting it) then the listing of these samples according to the values obtained for coefficient of expansion "to bring out their spalling resistance" is meaningless.

[1] "A Study of the Factors Involved in the Spalling of Fireclay Refractories with Some Notes on the Load and Reheating Tests and the Effect of Grind on Shrinkage," *Jour. Amer. Ceram. Soc.*, **8** [6], 361–82 (1925).

A number of the data shown on fireclay brick are far from complete and so are neither conclusive nor in a number of cases are they fair.

Since only one curve is plotted for brick from each of the Pennsylvania, Maryland, Missouri, and Colorado fireclay districts, and no mention is made of averages or check determinations, we assume that only one specimen was tested in each case. Certainly there was only one brand tested from each of the districts named. It hardly seems necessary to point out that one sample, or even one brand, of fireclay brick cannot ordinarily be chosen as being representative of the product of one manufacturer and that each of the districts named produces a wide variety of fireclay products. They vary in composition, grind, method of manufacture, and firing. It is not just, therefore, to assume that the brick tested by Norton represent the districts from which they came, that the average coefficient of expansion as given by him for fireclay brick will hold for other brands of brick, or that the statement, "fireclay brick start to shrink at about 1220°C," made in the conclusion, is an accurate one. Shrinkage, of course, depends upon composition, structure, and firing treatment, as is generally realized, and these are varied by the manufacturer to suit the needs of his customers. However, even the average shrinkage temperature given by Norton for fireclay brick is not an accurate one for his own results. The average is stated as being computed on samples 6, 7, 8, 9. For No. 6 he found a shrinkage temperature of 1320°C, no shrinkage on No. 7 at any temperature up to the highest used in the test (1600°C), 1250°C for No. 8, and 1100°C for No. 9. Using the value of 1600°C for No. 7 even though it showed no shrinkage at that temperature, the average is 1317°C, instead of 1220°C, as given. This, of course, has no more meaning than the figure given by Norton. There is some evidence that the determinations themselves were not accurate and that shrinkage was found at temperatures below the true ones. The kaolin brick fired at 1300°C are shown as shrinking at 1100°C and the rate of heating when the shrinkage was noted was 100°C per hour so that the time effect during the test was almost negligible. The specimen made from white Florida zircon was fired at 1650°C for two hours and yet shrank rapidly in the test at 1500°C. The specimen made from brown Florida zircon was fired for 4 hours at 1590° and yet began to shrink at 1550°C in the test where it was rapidly heated. Specimen No. 13 was made from Brazilian zirconia and fired at 1675°C for 8 hours. It shrank rapidly in the test at 1600°C. With the spinel brick shrinkage was found to take place 90°C below the stated firing temperature and 50°C below in the case of the fused alumina brick. A rather wide experience with refractory materials has never shown the writer a parallel case where

marked shrinkage took place during rapid heating and at temperatures well below the initial firing temperature, especially where the latter was held for a period of several hours' duration. If the firing temperatures are correctly given, we are inclined to believe that the shrinkage temperatures as observed are inaccurate and from 40°C to 200°C too low.

In dealing with the fireclay brick from Pennsylvania, the statement is made "above this temperature (1200°C) the specimen exhibited a peculiarity that is inherent in Pennsylvania clays and in few others. This is the so-called secondary expansion which starts in where most clay brick shrink and increases rapidly up to 5 or 6% at the softening point." This is in error in two ways. In the first place, the peculiarity of secondary expansion is only exhibited by flint clays from a rather definite locality in Pennsylvania and is not found on all or even a major percentage of flint clays from that State. In the second place, the expansion occurs only on soft-fired brick and does not necessarily take place even during the initial firing on medium- or hard-fired brick. Secondary expansion, therefore, is not an "inherent characteristic" of Pennsylvania brick.

In addition to those mentioned here, there are a number of other statements in this article to which exceptions might be taken, but they are not of first importance, and we do not want to cloud the issue by making this criticism of unnecessary length.

REPLY BY F. H. NORTON: Mr. Booze seems to have misinterpreted my purpose in listing the refractories in the order of their maximum coefficient of expansion. It was clearly stated that the tencendy to spall is proportional to the expansion coefficient if other properties are the same. In making a refractory of a given material, the coefficient of expansion can be altered but little, but the flexibility can be varied greatly by the structure and firing. This being true the coefficient of expansion of different materials gives the relative spalling possibilities of the manufactured refractory. For example, there is much more chance of making a good spallin brick out of silicon carbide than out of magnesite. There is no intention to infer that brick made from the materials listed would have the same order of spalling merit.

In giving data for the expansion of fireclay brick, it was not intended to give a complete or representative set. A few high grade brick were selected to bring out certain characteristic peculiarities in the expansion curves. The specimens are not necessarily typical of their region.

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[1] Received February 23, 1926.

In regard to the average shrinkage temperature of 1220°C, the average was made by considering that specimen No. 7 started to shrink at the temperature of permanent change in length (negative shrinkage). A number of other unpublished tests on fireclay refractories substantiate this average value. I have no reason to doubt the relation between the firing and shrinking temperature of the specimens, although the firing temperature was not determined with the precision of the temperatures in the expansion test.

The secondary expansion of flint clays may not be general in Pennsylvania but some of the best known brands of Pennsylvania brick exhibit this property. The brick showing secondary expansion in my paper was a well-fired commercial brick and would not be considered soft.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM FEBRUARY 16 TO MARCH 15.

PERSONAL

Louis Deverin, Professor of Mineralogy and Petrography at the University, Lausanne, Switzerland.

Waldemar F. Dietrich, Box A, Stanford University, California. Associate Professor of Mining and Ceramics.

Chas. M. Dodd, Box 268, New Philadelphia, Ohio. Student.

Carlo Ferrari, Colonial Hotel, 81st. & Col. Ave., New York City. Technical Manager, Societa Meridionale di Elettricila, Naples, Italy.

John M. Flanigen, Alliance, Ohio. Distribution Supt., Ohio Public Service Co.

Wm. G. Halloin, 904 Lock St., Tarentum, Pa. Lab. Asst., Research Dept., Pittsburgh Plate Glass Co.

Russell L. Hendricks, Lisbon, Ohio. R. Thomas and Sons Co.

Gustav Keppeler, Hannover, Korunstr. 11, Germany. Professor at the Technical High School.

Edward A. McNerney, 11 Kennedy St., Bradford, Pa. Plant Supt., Hanley Ceramics Society.

Henry M. Porter, Box 238, South Gate, Calif. Plant Manager, Calif. Clay Products Co.

Harry E. Potteiger, P. O. Box 23, Sinking Spring, Pa. Asst. Supt., Glen Gery Shale Brick Co.

Adrian T. Preston, Safe-Cabinet Laboratory, Marietta, Ohio. Chemist.

Chas. N. Skalla, Rua Andrade Neves 56, Rio de Janeiro, Brazil.

Willard G. Young, Box F, Sta. A., Ames, Iowa. Student.

Eberhard Zschimmer, Boeckh-Str. 4, Karlsruhe (Germany). Professor in the Technical High School.

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Harper Electric Furnace Corp., 400 Bankers Trust Bldg., Philadelphia, Pa. H. P. Rust, Representative.

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Roy A. Horning	1	Office	7	3
Francis T. Owens	1		15	3

PERSONAL NOTES OF MEMBERS

Eugen Becher is now corporation representative of the Metal & Thermit Corp. in place of Homer F. Staley.

Wm. J. Bidleman, formerly at Wellsville, Mo. with the Wellsville Fire Brick Co., is situated with the Chicago Fire Brick Co., Chicago, Ill.

Wm. K. Booth of Chicago has moved to Sierra Madre, Calif.

H. R. Borland has changed his residence from Peoria, Ill. to Thurber, Texas.

Geo. E. Crawford has moved from Trenton, N. J. to Academy Apts., Kittanning, Pa.

E. A. Eigenbrot of St. Louis is no longer with the Bucks Stove & Range Co. but is now associated with the J. B. Ford Co.

Francis E. Finch has been designated corporation representative of the Hardinge Co. in place of Harlowe Hardinge.

Walter L. Fitzgerald, formerly with the Haws Refractories Co., Philadelphia, Pa., is now Vice President of the United Clay Mines Corp., Trenton, N. J.

R. B. Gilmore has recently moved to Lock Haven, Pa., where he is located with the Queen's Refractories Co. Mr. Gilmore was formerly with the Carborundum Co., Niagara Falls, N. Y.

Virgil K. Haldeman is now located at 1061 Alameda St., Burbank, Calif. He was formerly with the Beaver Falls Art Tile Co., Beaver Falls, Pa.

R. B. Keeler is no longer with the California Clay Products Co. but is located at 8175 Victoria Ave., South Gate, Calif.

E. Kenneth Koos is now with the D. E. McNicol Pottery Co., Clarksburg, W. Va. Mr. Koos has been connected with the Red Wing Union Stoneware Co. of Red Wing, Minn.

J. S. Leibson, who has been in this country for some time, has returned to France where he is with the Porcelainerie de Lesquin at Lesquin-les-Lille.

C. C. Leigh has recently become manager of the Belmont Tumbler Co. at Bellaire, Ohio. Mr. Leigh was previously located at Philadelphia with Gillinder & Sons, Inc.

Los Angeles Pressed Brick Co. and **Gladding-McBean & Co.** are now jointly occupying rooms in the New Pacific Finance Bldg., 621 S. Hope St., Los Angeles, Calif.

C. G. Powell has moved from Montezuma, Ind. to 512 Maurry St., Alcoa, Tenn.

Ernest C. Schmatolla has left the A. C. Spark Plug Co. in Flint, Mich. and is now located in New York City.

H. P. Smith has been substituted for Malcolm McNaughton as representative of the Joseph Dixon Crucible Co.

NOTES AND NEWS

REPORT OF COMMITTEE ON BOILER FURNACE REFRACTORIES[1]

The organization meeting of the Special Research Committee on Boiler Furnace Refractories was held at the Engineers' Club, New York City. The following persons attended: C. F. Hirshfeld, Chairman, G. A. Bole, M. C. Booze, R. F. Geller, C. W. Parmelee, J. S. McDowell, E. B. Ricketts, and O. P. Hood. Guests: R. A. Sherman, P. Nicholls, W. H. Fulweiler, W. A. Carter, C. B. LePage, and Chas. Taylor.

C. F. Hirshfeld outlined briefly the steps which have led to the organization of this Committee. As a purely individual activity he had during the past 15 months collected certain funds which he had placed at the disposal of the Bureau of Mines to cover the expenses of a beginning in a research on boiler furnace refractories. At the suggestion of O. P. Hood, Director of the Bureau of Mines, Mr. Hirshfeld called this activity to the attention of the A. S. M. E. Main Research Committee and suggested its acceptance as one of the A. S. M. E. projects. This suggestion was favorably received by the Main Committee and on its recommendation the Council approved the organization of the Committee to carry forward this investigation. The Main Committee asked Mr.

[1] Tuesday, December, 1, 1925.

Hirshfeld to accept the Chairmanship and with his help has named the personnel of the Special Committee.

Mr. Hirshfeld informed the Committee that two progress reports had appeared in the August 18th and August 25th, 1925 issues of *Power*. These reports cover the important details relating to this research. He explained that no one material or form of material was to be investigated but that the research was to be conducted on broad and general lines in a search for information which would be of use to both the manufacturer and the user.

Ralph A. Sherman, Assistant Physicist of the Pittsburgh Experiment Station of the Bureau of Mines, gave a brief report on his work in this investigation. He said that the plan of attack called for the following four distinct movements: (1) to determine as definitely as possible the principal factors governing the failure of refractories in various types of installation, (2) to subject these factors to a detailed experimental analysis, (3) to undertake the formulation of tests that will measure the suitability of the tested material for the given conditions, and (4) to attempt the development of a suitable refractory, in case such a refractory is not available for a given service.

He discussed each of these items briefly and stated that he had made visits to more than 34 stations where careful inspection was made of boilers having various furnace sizes. These furnaces are fired by under-feed, chain grate and over-feed stokers, pulverized coal burners, fuel oil burners and natural gas burners.

G. A. Bole, Superintendent of the Ceramic Experiment Station, Bureau of Mines, described the preliminary experiments which have been carried on in his laboratory on sample refractories of various grain size and composition. He said these samples had various alumina-silica ratios and that some were hand made and others were produced by dry press processes. He expressed the opinion that this investigation was largely a fire clay refractory problem and said that his laboratory was planning (1) to study the action of slag on fire brick and then (2) to test various commercial refractories for freedom from the effects of slag.

CALENDAR OF CONVENTIONS

Amer. Assn. of Flint and Lime Glass Mfgrs.	April, 1926	Wheeling, W. Va.
AMERICAN CERAMIC SOCIETY		
Summer Meeting	July, 1926	Philadelphia, Pa.
Annual Meeting	Feb., 1927	Detroit, Mich.
Amer. Chemical Society		
Spring Meeting	April 5–9, 1926	Tulsa, Okla.
Amer. Electrochemical Soc.	April 22–24, 1926	Chicago, Ill.
Amer. Foundrymen's Assn.	Sept. 27, 1926	Detroit, Mich.
Amer. Gas Assn.	Oct. 11–14, 1926	Atlantic City, N. J.
Amer. Inst. Chem. Engrs.	June 21–23, 1926	Berlin, N. H.
Amer. Mining Congress	December, 1926	Washington, D. C.
Amer. Refractories Inst.	April 13, 1926	Pittsburgh, Pa.
Amer. Soc. Mech. Engrs.	Dec. 6–9, 1926	New York City
Amer. Soc. Testing Materials	June 21–26, 1926	Atlantic City, N. J.
Amer. Zinc Inst.	April 27–28, 1926	St. Louis, Mo.
Assn. Chem. Equipment Mfrs.	May 10–15, 1926	Cleveland, Ohio
Assn. Iron and Steel Mfrs.	May 31–June 5, 1926	Chicago, Ill.
The Ceramic Society of England	April 12, 1926	Stoke-on-Trent, Eng.
Chamber of Commerce of U. S.	May 10–13, 1926	Washington, D. C.
Illinois Clay Mfrs.	April 13, 1926	Urbana, Illinois
Manufacturing Chemists' Assn.	May or June, 1926	Near New York City
Natl. Acad. of Sciences		
Spring Meeting	April 26–28, 1926	Washington, D. C.
Natl. Assn. of Mfrs.	Oct. 20–22, 1926	New York City
Natl. Assn. Stove Mfrs.	May 12–13, 1926	New York City
Natl. Safety Council	Oct. 4–9, 1926	Detroit, Mich.
Natural Gas Assn. of Amer.	May 17–20, 1926	Tulsa, Okla.
N. J. Clayworkers' Assn.	June, 1926	Trenton, N. J.
Ohio Ceramic Industries Assn.	Oct., 1926	Columbus, Ohio
Stained Glass Assn. of Amer.	May 12–14, 1926	Washington, D. C.

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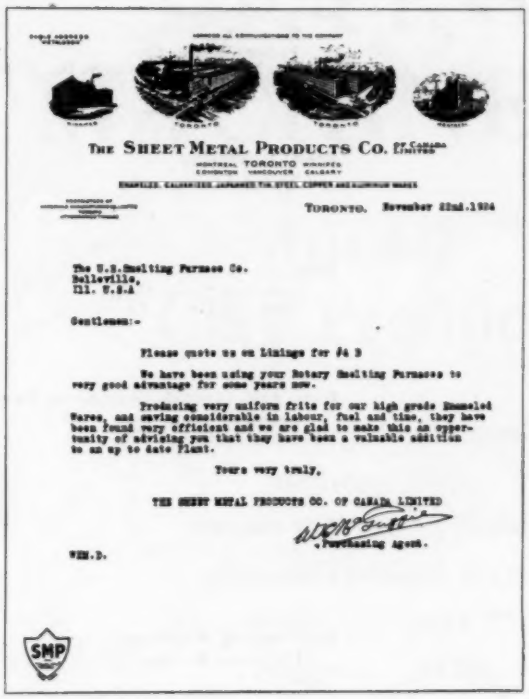

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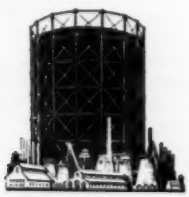

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These twelve states—North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Tennessee, Arkansas, Virginia and Kentucky—constitute the South's 5 million dollar Floor and Wall Tile Market which can be more effectively served from a branch plant located in Georgia, because of unusual economic advantages.

The Present and Future Floor and Wall Tile Markets of the South—
The existing market, although running up to an average of 5 million dollars annually, is served solely by plants located north of the Ohio and Potomac Rivers at comparatively high freight costs due to long hauls of raw materials and finished tile. There are no plants of any consequence manufacturing high grade floor and wall tile in the South. With the South's ever increasing building operations—a development that is certain to be active for many, many years to come—the future floor and wall tile market is a most promising one.

The Economy of Assembling Raw Materials—
Practically all of the raw materials used in the manufacture of floor and wall tile, such as Kaolin, Ball Clay, Feldspar, Flint and Sagger Clay are availabe in abundance in the Southern States. Today these raw materials are hauled out of Southern States to distant Northern points for the manufacture of tile, and finished tile has to be shipped back again to meet the demand of the Southern market! Think of the tremendous cost for assembling raw materials and the distribution of finished tile to the South! A branch plant located in Georgia can save approximately 40% on raw material assemblage costs.

Low Distribution Cost of Finished Tile—
Likewise, a branch plant located in Georgia, serving the Southern Floor and Wall Tile Market, would enjoy a considerably lower distribution cost as well as a lower raw material assemblage cost. As compared with two notable Northern floor and wall tile manufacturing centers, the favorable freight rates on finished tile to large cities of the South from a plant located in Georgia, afford considerable savings in distribution cost.

Building Material Costs are Low—
The following figures are the average costs of building materials in Georgia—Common building brick $11 to $14 per thousand. Cement $3 per barrel. Crushed Stone $1.25 to $1.65 per ton. Lumber $24 to $60 per thousand feet.

Favorable Labor and Fuel Costs—
Common labor costs run from 20 to 40 cents per hour. Fuel oil at present ranges from 6½ to 7¼ cents per gallon. Coal costs from $3.50 to $4.50 per ton. Hydro-electric power lines cover the western, middle and northern sections of Georgia.

ASK OUR COOPERATION—We have compiled much valuable and up-to-date information and statistics on the possibilities of Floor and Wall Tile manufacture in Georgia, that is available without charge or obligation to establish Floor and Wall Tile Manufacturers, seriously contemplating the de-centralization of operations. Ask us about Georgia as a location for your branch plant.

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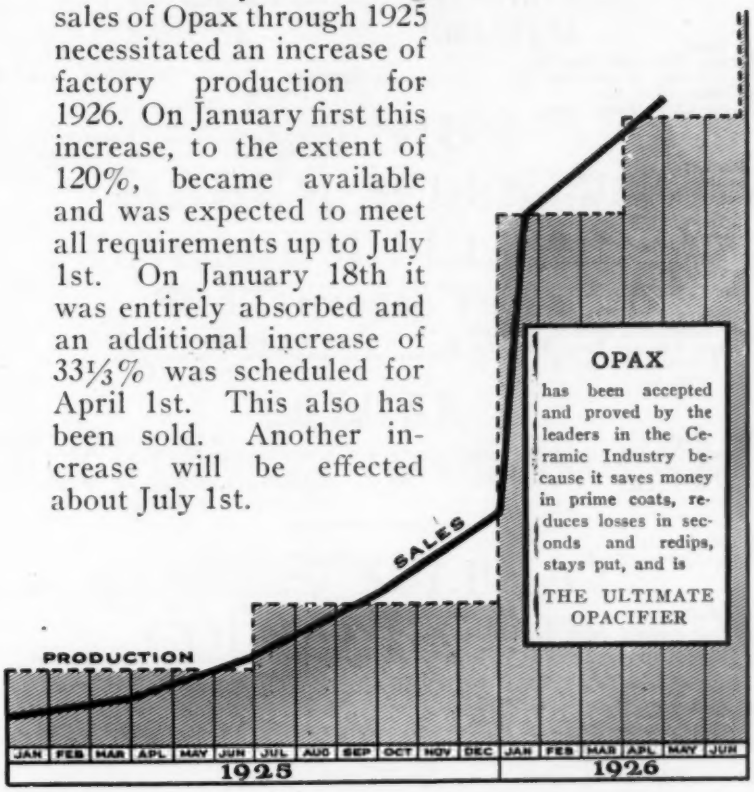

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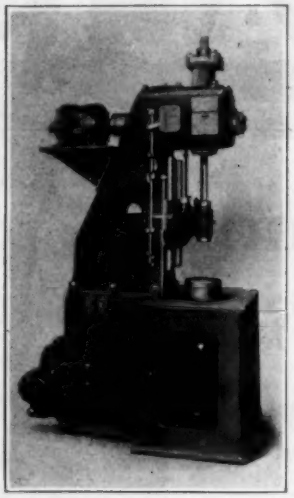

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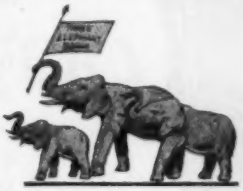

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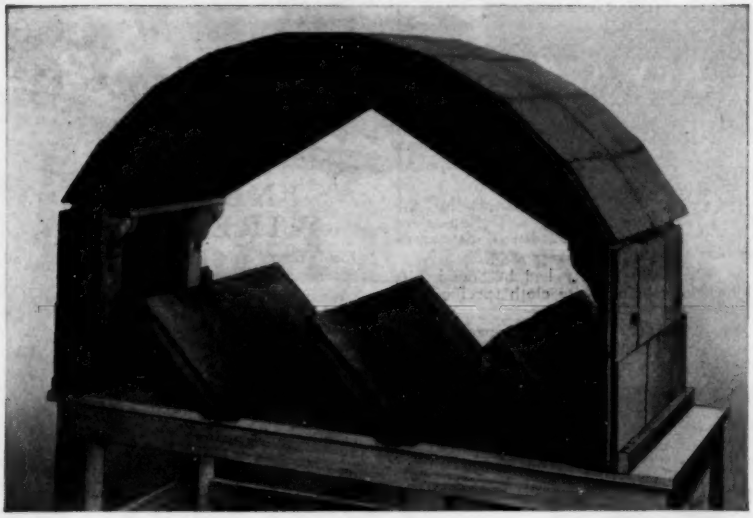

Section of Alundum Muffle for Vitreous Enameling Furnace. Wall and arch tiles—Ferro Enameling Supply Company design. Bottom—Manion "V-Bottom." Width, 5 feet. Side walls, 15 inches. Rise, 15 inches.

Alundum Enameling Muffles

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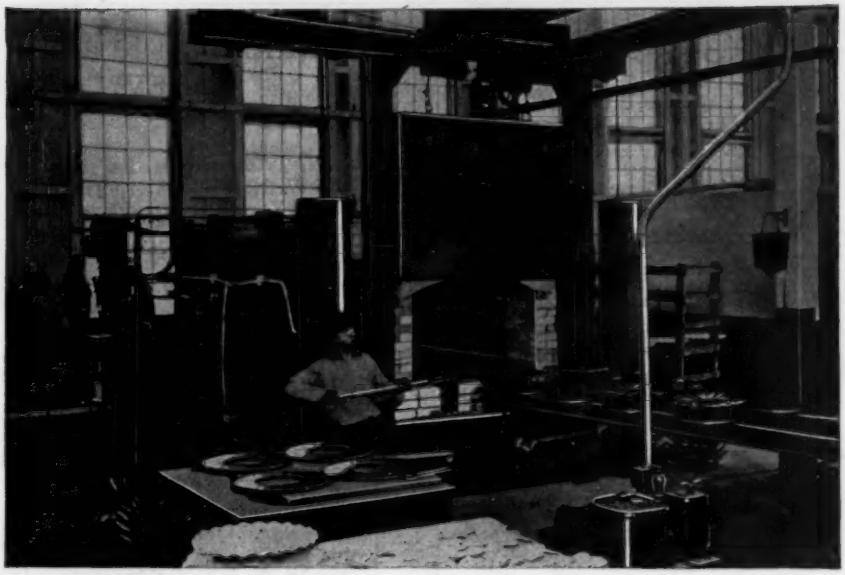

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The Ferro Enamel Supply Co., Cleveland, Ohio, announces the addition of Mr. F. S. Markert to their Engineering Department. Mr. Markert is a graduate of the University of Illinois and was formerly with the Belleville Enameling and Stamping Company.

Mr. E. O. McFadon is now representing the Ferro Enamel Supply Company in the St. Louis district. Mr. McFadon was formerly with Ferro in Cleveland.

The Globe Stove and Range Company of Kokomo, Indiana, is installing a large and up-to-date porcelain enameling department. Engineering and all equipment is being furnished by The Ferro Enamel Supply Company of Cleveland, Ohio.

The Kalamazoo Stove Company of Kalamazoo, Michigan, has awarded contract to The Ferro Enamel Supply Company at Cleveland for a complete new porcelain enameling department.

CERAMIC BREVITIES

R. T. Dinwiddie has joined the W. N. BEST Corporation, New York City in charge of their Ceramic Oil Burning Division.

Mr. Dinwiddie's activities in the ceramic field include several years in charge of the production of high temperature refractories at the East Liverpool plant of the Babcock & Wilcox Co., and later as factory manager of the J. H. Gautier Co., Jersey City, N. J.

His long experience in the oil firing of ceramics renders his services of great value to the W. N. BEST Corporation and their customers.

At a recent Board of Directors meeting, the following were elected as Officers and Directors of the Wolverine Porcelain Enameling Co., Detroit, Mich.

Mr. Heinrich Turk, Mr. Karl Turk, both of the Porcelain Enameling and Mfg. Co., Baltimore, Md., President and Vice-President, respectively; Mr. John A. Frey, of the Detroit Mich. Stove Co., Vice-President; Mr. A. B. Moran, of the Penninsular Stove Co., Secretary and Treasurer. Mr. Jos. Hoehl of Wolverine Porcelain Enameling Co., Assistant Secretary.

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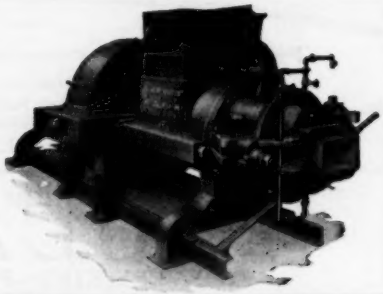

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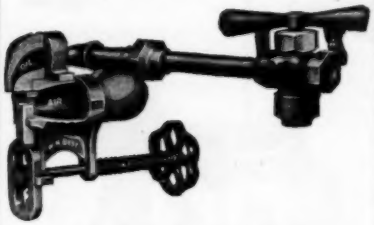

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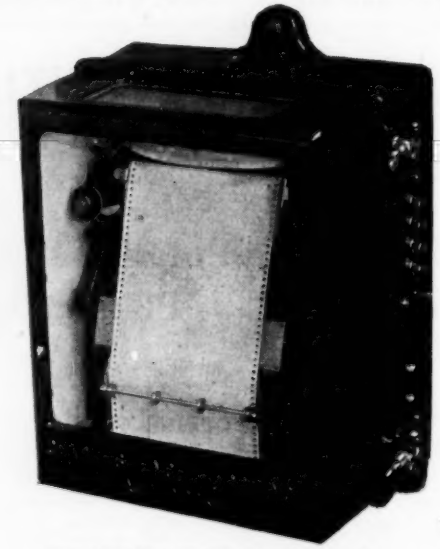

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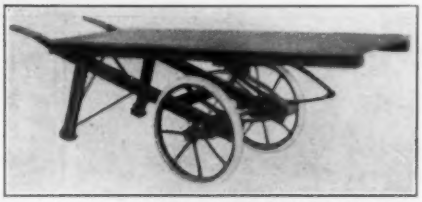

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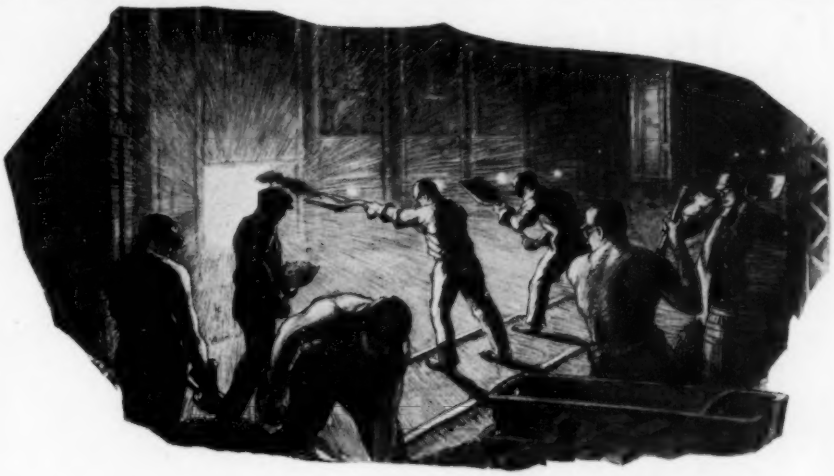

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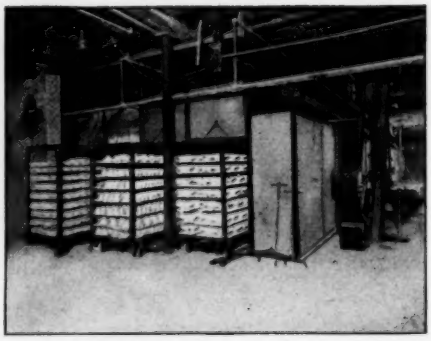

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